THERMO UTILITIES
MS EXCEL ADD-INS

Version 3.5 for 32-bit Excel 97-2003, 2007, 2010 and higher

Release Date: June 24, 2013

DISCLAIMER - AGREEMENT

Users of Thermo Utilities must accept this disclaimer of warranty: Thermo Utilities is supplied as is. The author disclaims all warranties, expressed or implied, including, without limitation, the warranties of merchantability and of fitness for any purpose. The author assumes no liability for damages, direct or consequential, which may result from the use of Thermo Utilities.

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Update and Upgrade History

Upgrade note for version 3.5, release date June 15, 2013

- *Compatibility with latest release of Excel, Win 7 and Win 8*
- *Fluid Properties is now a freeware.*
- *The database interface of fluid properties are replaced with table look up.*

Upgrade note for version 3.0, release date Jan. 12, 2000

- *Adding Lee-Kesler method to the package.*
- *Adding a database with properties of more than 450 chemicals*

Update note for version 2.05, release date Jan. 25, 1999

Optimizing stmxl.dll

Update note for version 2.03, release date Dec. 30, 1998

Bug fixes in unit.xla

Update note for version 2.02, release date Sept. 30, 1998

Bug fixes

Release note for version 2.01, release date Sept. 14, 1998

Support for MS Excel 7, 97, Office 97 and higher (32-bit)

Release note for version 2.0, release date Sept. 10, 1998

Thermo Utilities v2.0 is a software package developed for engineers and scientists, who wish to design, analyze or optimize power plants and air conditioning systems. It supports MS Excel 5.0 (16-bit) and it will run on PC platforms with operating systems, Win 3.1, Win 95, Win 98, Win NT 3.51 and higher.

It offers a large number of functions for calculating the properties of water, steam, air and flue gases. The functions used for steam and water properties are based on a set of equations accepted by the members of the Sixth International Conference on the Properties of Steam. The sets of equations are also known as "IFC Formulation for Industrial Use". Thermo Utilities calculates the properties of dry air, moist air, exhaust and flue gases by using equations accepted by ASHRAE and CIBSE (Chartered Institute of Building Services Engineers).

The package also offers a large number of inverse functions which are useful for applied thermodynamics calculations. For more details see the help file that comes with this package.

The earlier version of this package has been offered as a bonus to the registered users of:

- *Steam properties v1.2 and higher*
- *Air and exhaust gas properties v1.2*

Brief Description and Downloading

Thermo Utilities v3.5 is a software package developed for engineers and scientists, who wish to design, analyze or optimize power plants, air conditioning systems and other chemical processes. It supports 32-bit version of MS Excel i.e. Excel 97-2003, Excel 2007, Excel 2010 and higher and it will run on PC platforms with operating systems Win XP, Vista, Win 7 and Win 8 and higher. We have supported older Excel version since 1995. If you need this application to run on older versions of Windows OS and Excel, please contact us.

Thermo Utilities offers a large number of functions for calculating the properties of water, steam, air, flue gases and other fluids. The functions used for steam and water properties are based on a set of equations accepted by the members of the Sixth International Conference on the Properties of Steam. The sets of equations are also known as "**IFC Formulation for Industrial Use**". Thermo Utilities calculates the properties of dry air, moist air, exhaust and flue gases by using equations accepted by **ASHRAE** and **CIBSE** (Chartered Institute of Building Services Engineers). **Lee-Kesler method** used in this package can be applied to a large number of chemicals for estimating thermodynamic properties. The database accompanied with this package for use with Lee-Kesler method supports more than 450 chemicals. The package also offers a large number of inverse functions which are useful for applied thermodynamics calculations. The features are:

- Support for VBA (Visual Basic for Application)
- User selectable units for inputs/outputs
- Calculates enthalpy, entropy, specific volume, dryness fraction, specific heat capacity, thermal conductivity, and dynamic viscosity
- All inverse functions, needed in applied thermodynamics applications, are provided. More about this can be found in the help files.
- Chemical compound database for: normal freezing point, normal boiling point, critical pressure, critical temperature, critical specific volume, critical compressibility factor, Pitzer's acentric factor, dipole moment, standard enthalpy of formation and Gibb's energy of formation.

Link for downloading the latest version: http://www.taftan.com/tuxl30.zip

There are also a number of worksheets (http://www.taftan.com/xl/index.htm) available for registered users. These worksheets cover combustion of coal, biomass and fossil fuel, compressor, condenser design, cooling with dehumidification, closed-feed heaters, gas turbine, mixing of two air stream, regenerative steam cycle, sensible cooling/heating process, steam turbine and steam valve/throttling process.

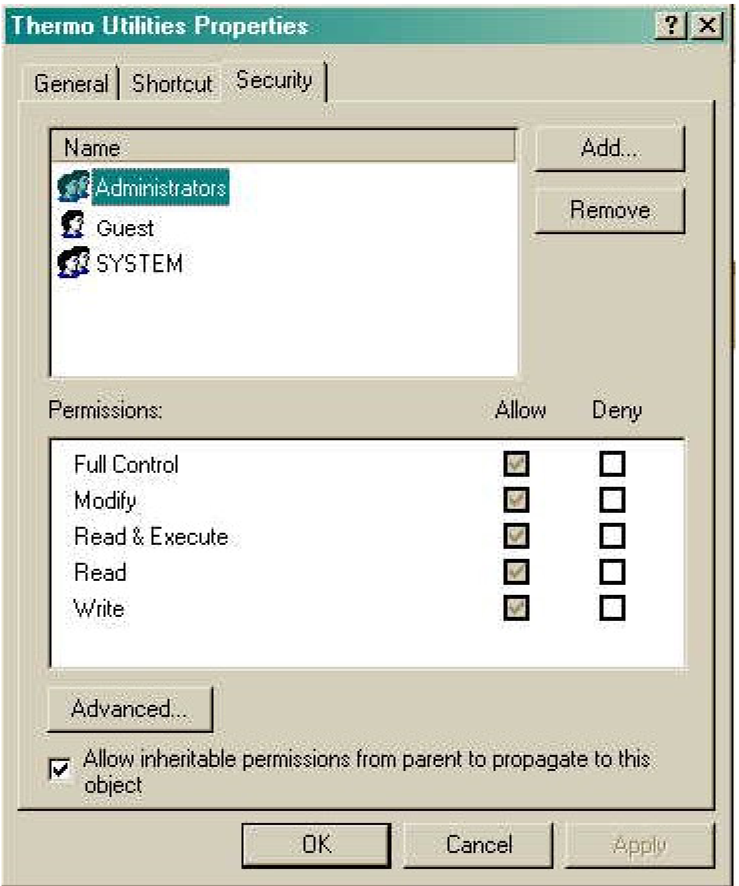
How to install Thermo Utilities

You must have approximately 15.0 Mb of free disk space to install the program. Before you install "Thermo Utilities", please make sure that:

- You have installed the latest "Service Pack" for Windows operating system,
- You have installed the latest "Service Pack" for your "EXCEL" or "Office" software.

The installation procedure is as follows:

- In case, you need to login into your computer to use it, you should login as administrator to install the software.
- Copy "TUXL30.ZIP" to a suitable folder and unzip the file to folder "C:\THERMOXL"
- Attention: The software is made of many components. Each component search for other parts in the folder "C:\THERMOXL"
- Path to "Air and Flue Gas Properties" is: "C:\THERMOXL\AIRXL.XLA"
- Path to "Steam and Water Properties" is: "C:\THERMOXL\STMXL.XLA"
- Path to "Lee-Kesler method" is: "C:\THERMOXL\LKXL.XLA"
- Path to "Unit Conversion" is: "C:\THERMOXL\UNIT.XLA"
- Run "C:\THERMOXL\SetUnit.exe" and select the desired units.
- While you are logged in as administrator, you should give access to the software to all users that are allowed to use the software.



For doing this, click on Windows "start" button, select "Computer" then select "C:\THERMOXL" folder and then right click with mouse, select properties, select security, among the following options for the user (Full Control, Modify, Read & Execute, Read & Write) select "Full Control" and push "OK" button. The following instructions are Windows Vista only:

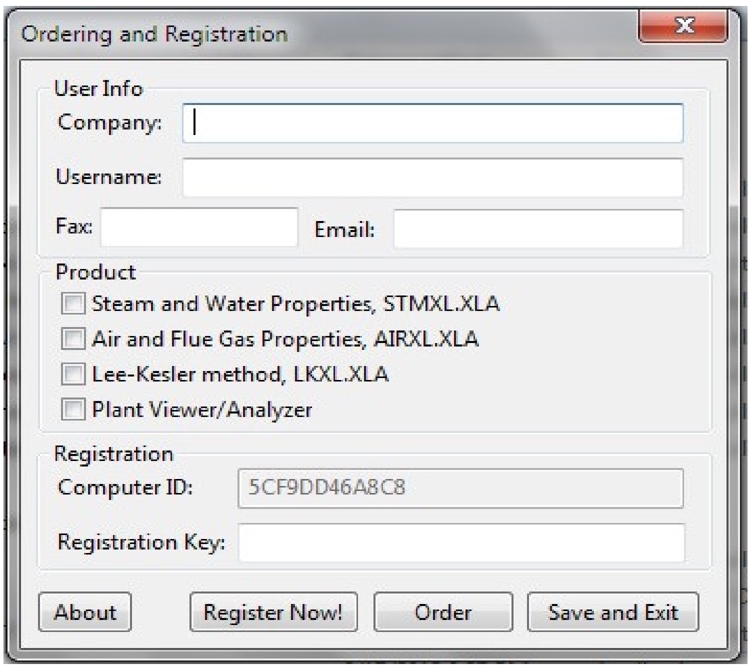
1. Click Start and Control Panel.
2. Switch to Classic View (if you haven't already) and click on the Administration Tools icon.
3. In the list that opens click on Local Security Policy, and in the next window, Local Policies (a tiny bit redundant, but all UIs can't be perfect -- If UAC is running you'll get a UAC pop-up somewhere in here).
4. In the Local Policies list click Security Options, and scroll down to "User Account Control: Behavior" (the full title of the policy is "User Account Control: Behavior of the elevation prompt for administrators in Admin Approval Mode" but the window barely opens that far).
5. Double-click the title and in the dialog box change its setting from "Prompt for Consent" to "Elevate without prompting."

How to Order Your Registration Key

Before ordering your registration key, please check that everything works on your computer. Many functions of Thermo Utilities v3.5 should work even if you do not have a registration key. If there is any problem, do not hesitate to contact us. We solve all the problems, before you order our product. When you order you will receive your registration key that enables all the functions. It is not possible to transfer the registration key from one computer to other. If you wish to order your registration key, please run the program *C:\THERMOXL\register.exe* and:

1. Type your name, company name, fax number and your email address (blank if not applicable)
2. Select the Add-ins you wish to order
3. Press the Order button
4. Email us the software generated "order.txt". The file location is: "C\THERMOXL\order.txt"
5. Pay the registration fee

Here is a screenshot of ordering and registration utility:



How to Pay the Registration Fee

The prices of the registration keys are:

- Air and Flue Gas Properties, MS Excel Add-ins 139 USD
- Steam and Water Properties, MS Excel Add-ins 149 USD
- Lee-Kesler method, MS Excel Add-ins 159 USD

In order to place your order, you need to visit our website at:

http://www.taftan.com/thermoxl.shtml

Once you click on the link for ordering, you will be connected to our order taking company SWREG. SWREG is a global cloud commerce solution. They offer numerous payment options and currencies, including phone and fax order support in many countries.

Finalizing the Registration

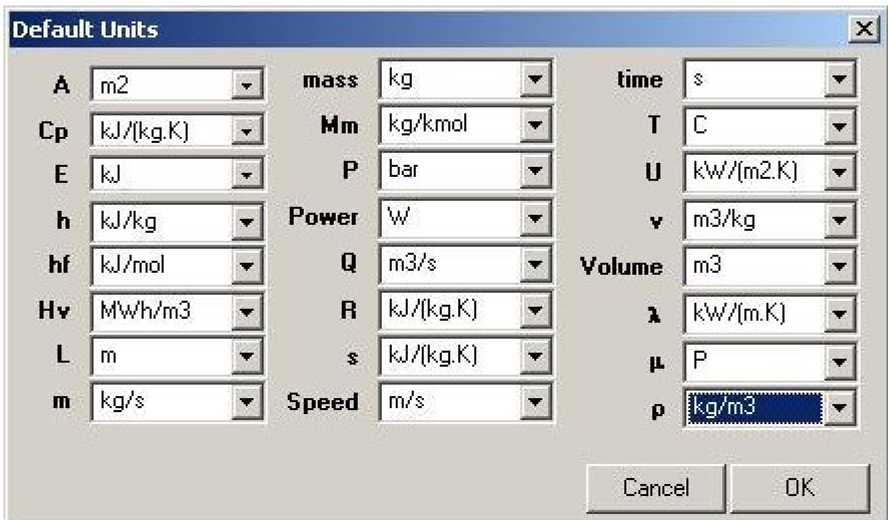
Once you receive your registration key from us, you run the program "**Register.exe**" one more time. You select the application you would like to register, type (or cut and paste) the registration key and click on the button "**Register Now**!". If all is good, the software will show a dialog box with message "**Successful Registration!**". Press "OK" and continue.

If there is more than one application to register, you can repeat the same procedure again.

At the end, do not forget to click the button "Save and Exit.

Unit Selection

Thermo Utilities supports a large number of units for inputs and outputs. Run the program "**C:\THERMOXL\SetUnit.exe**" before you start your calculations. Select your desired units. In case you are running “SetUnit.exe” while Excel is running, you need to restart Excel to force it to use newly selected units. Below here you will see a screenshot of "SetUnit.exe".



The unit conversion will apply to both inputs and outputs. If you activate "UNIT.XLA", you can use the strings for the current unit in your worksheet, which improves the readability and security of your calculations. It should be mentioned that Cv, specific heat capacity at constant volume has the same unit as Cp. Steam quality or dryness fraction and Gamma are dimensionless parameters.

How to Activate Functions for MS Excel 2010

In order to activate steam/water functions in MS Excel perform the following procedure:

1. Start your Excel program
2. Click on "File" and Select "Options", a new dialog box called "Excel Options" will open.
3. In the dialog box click on "Add-Ins" on the left side of the window.
4. Make sure the option in front "Manage" points to "Excel Add-ins".
5. Click on the button "Go ...". A new dialog box will open.

Then browse and select C:\THERMOXL\STMXL.XLA

For air and flue gas functions browse and select C:\THERMOXL\AIRXL.XLA

For Lee-Kesler method functions browse and select C:\THERMOXL\LKXL.XLA

For unit conversion function browse and select C:\THERMOXL\UNIT.XLA

You can deactivate any of these groups of functions by deselecting them.

How to Activate Functions for MS Excel 2007

In order to activate steam/water functions in MS Excel perform the following procedure:

1. Start your Excel program
2. Click the Microsoft Office Button, and then click Excel "Options".
3. Click the Add-Ins category.
4. In the "Manage" box, click "Excel Add-ins", and then click "Go ...".

Then browse and select C:\THERMOXL\STMXL.XLA

For air and flue gas functions browse and select C:\THERMOXL\AIRXL.XLA

For Lee-Kesler method functions browse and select C:\THERMOXL\LKXL.XLA

For unit conversion function browse and select C:\THERMOXL\UNIT.XLA

You can deactivate any of these groups of functions by deselecting them.

How to Activate Functions for MS Excel 97-2003

In order to activate steam/water functions in MS Excel perform the following procedure:

1. Start your Excel program
2. Select "Tool"
3. Select "Add-ins"

Then browse C:\THERMOXL\STMXL.XLA

For air and flue gas functions browse and select C:\THERMOXL\AIRXL.XLA

For Lee-Kesler method functions browse and select C:\THERMOXL\LKXL.XLA

For unit conversion function browse and select C:\THERMOXL\UNIT.XLA

You can deactivate any of these groups of functions by deselecting them.

List of Functions for properties of steam/water

When you activate STMXL.XLA, you have access to all steam/water functions. By clicking on

button in MS Excel a dialog over all function comes up. Select "**User Defined**" and you will have a list over all user defined functions. When you pick a function, a brief description of the function appears at the bottom of the dialog box. If you press "Next", Excel will continue with a dialog box that asks for the necessary inputs for the function. In case, you press "Enter" button, you should fill all the parameters with numbers, cell reference, variable’s name and so on. These are the normal Excel functions behavior and are not specific for this program. If you need more help please see the on-line help of MS Excel or the user manual. The function names are compatible with the DLL version of the software. User who upgrade to this version from DLL version, will find several new functions. There are some simple rules that will help you to remember functions’ names. Here, you have a complete list of functions for properties of steam and water:

Function	Description	Comment
STMCp	(P,T)-->Cp, Heat capacity	Returns 0 in demo version.
STMCpSS	(P)-->Cp for saturated steam	Returns 0 in demo version.
STMCpSW	(P)-->Cp for saturated water	Returns 0 in demo version.
STMDv	(V,T)-->Dv, Dynamic viscosity	Returns 0 in demo version.
STMPHQ	(P,H)-->Q, Dryness fraction	Returns 0 in demo version.
STMPHS	(P,H)-->S, Specific entropy	Returns 0 in demo version.
STMPHT	(P,H)-->T, Temperature	Returns 0 in demo version.
STMPHV	(P,H)-->V, Specific volume	Returns 0 in demo version.
STMPQH	(P,Q)-->H, Specific enthalpy	Returns 0 in demo version.
STMPQS	(P,Q)-->S, Specific entropy	Returns 0 in demo version.
STMPQV	(P,Q)-->V, Specific volume	Returns 0 in demo version.
STMPSH	(P,S)-->H, Specific enthalpy	Returns 0 in demo version.
STMPSQ	(P,S)-->Q, Dryness fraction	Returns 0 in demo version.
STMPST	(P,S)-->T, Temperature	Returns 0 in demo version.
STMPSV	(P,S)-->V, Specific volume	Returns 0 in demo version.
STMPT	**(P)-->T, Saturation temperature**	**Should work in demo version.**
STMPTH	(P,T)-->H, Specific enthalpy	Returns 0 in demo version.
STMPTS	(P,T)-->S, Specific entropy	Returns 0 in demo version.
STMPTV	(P,T)-->V, Specific volume	Returns 0 in demo version.
STMPVH	(P,V)-->H, Specific enthalpy	Returns 0 in demo version.
STMPVQ	(P,V)-->Q, Dryness fraction	Returns 0 in demo version.
STMPVS	(P,V)-->S, Specific entropy	Returns 0 in demo version.
STMPVT	(P,V)-->T, Temperature	Returns 0 in demo version.
STMTc	(V,T)-->Tc, Thermal conductivity	Returns 0 in demo version.
STMTP	**(T)-->P, Saturation pressure**	**Should work in demo version.**
STMTQH	(T,Q)-->H, Specific enthalpy	Returns 0 in demo version.
STMTQS	(T,Q)-->S, Specific entropy	Returns 0 in demo version.
STMTQV	(T,Q)-->V, Specific volume	Returns 0 in demo version.

List of Functions for Properties of Air/Flue Gases

Functions for properties of air/flue gases are based on equations accepted by ASHRAE and are compatible with formulations accepted by CIBSE (Chartered Institute of Building Services Engineers). When you activate AIRXL.XLA, you have access to all air/flue gases functions. By clicking on

button in MS Excel a dialog over all function comes up. Select "**User Defined**" and you will have a list over all user defined functions. When you pick a function, a brief description of the function appears at the bottom of the dialog box. If you press "Next", Excel will continue with a dialog box that asks for the necessary inputs for the function. In case, you press "Enter" button, you should fill all the parameters with numbers, cell reference, variable's name and so on. These are the normal Excel functions behavior and are not specific for this program. If you need more help please see the on-line help of MS Excel or the user manual. The function names are compatible with the DLL version of the software. User who upgrade to this version from DLL version, will find several new functions. There are some simple rules that will help you to remember functions' names. Here, you have a complete list of functions for properties of Air and Exhaust Gas:

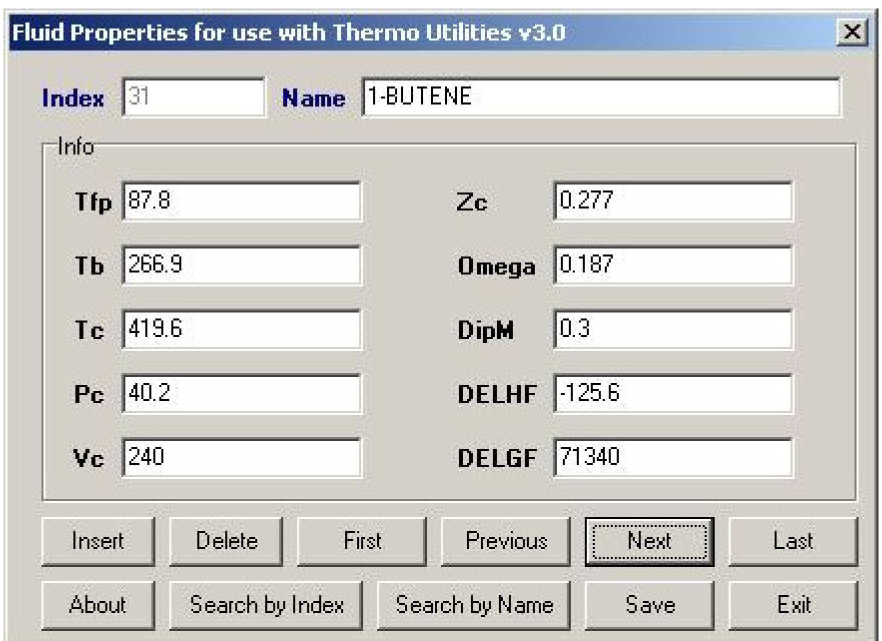
Function	Description	Comment
AirCpT	(mc,Cp)-->T, Temperature	Returns 0 in demo version.
AirDpt	(mc,P)--> Dpt, Dew point temperature	Returns 0 in demo version.
AirDv	(mc,P,T)-->Dv, Dynamic viscosity	Returns 0 in demo version.
AirGC	**(mc)-->Gc, Gas constant**	**Should work in demo version.**
AirHT	(mc,H)-->T, Temperature	Returns 0 in demo version.
AirMM	**(mc)-->Mm, Molecular mass**	**Should work in demo version.**
AirST	(mc,S)-->T, Temperature	Returns 0 in demo version.
AirTc	(mc,P,T)-->Tc, Thermal conductivity	Returns 0 in demo version.
AirTCp	(mc,T)-->Cp, Heat capacity at constant P	Returns 0 in demo version.
AirTCv	(mc,T)-->Cv, Heat capacity at constant V	Returns 0 in demo version.
AirTGamma	(mc,T)-->Gamma = Cp/Cv	Returns 0 in demo version.
AirTH	(mc,T)-->H, Specific enthalpy	Returns 0 in demo version.
AirTS	(mc,T)-->S, Specific entropy	Returns 0 in demo version.
FlueCpT	(Cp,%)-->T, Temperature	Returns 0 in demo version.
FlueDpt	(P,%)--> Dpt, Dew point temperature	Returns 0 in demo version.
FlueDv	(P,T,%)-->Dv, Dynamic viscosity	Returns 0 in demo version.
FlueGC	**(%)-->Gc, Gas constant**	**Should work in demo version.**
FlueHT	(H,%)-->T, Temperature	Returns 0 in demo version.
FlueMM	**(%)-->Mm, Molecular mass**	**Should work in demo version.**
FlueST	(S,%)-->T, Temperature	Returns 0 in demo version.
FlueTc	(P,T,%)-->Tc, Thermal conductivity	Returns 0 in demo version.
FlueTCp	(T,%)-->Cp, Heat capacity at constant P	Returns 0 in demo version.
FlueTCv	(T,%)-->Cv, Heat capacity at constant V	Returns 0 in demo version.
FlueTGamma	(T,%)-->Gamma = Cp/Cv	Returns 0 in demo version.
FlueTH	(T,%)-->H, Specific enthalpy	Returns 0 in demo version.
FlueTS	(T,%)-->S, Specific entropy	Returns 0 in demo version.
GasDensity	**(P,T,Gc)-->Density**	**Should work in demo version.**
GasS	**(P,Gc,Satm)-->S at pressure, P**	**Should work in demo version.**
GasSAtm	**(P,Gc,S)-->Satm = S at atmospheric pressure**	**Should work in demo version.**
ScreenPS	(DBT,WBT)-->PS, Percentage saturation	Returns 0 in demo version.
ScreenRH	(DBT,WBT)-->RH, Relative humidity	Returns 0 in demo version.
ScreenSH	(DBT,WBT)-->SH, Specific humidity	Returns 0 in demo version.
ScreenVWR	(DBT,WBT)-->VWR, Volumetric water ratio	Returns 0 in demo version.
SlingPS	(DBT,WBT)-->PS, Percentage saturation	Returns 0 in demo version.
SlingRH	(DBT,WBT)-->RH, Relative humidity	Returns 0 in demo version.
SlingSH	(DBT,WBT)-->SH, Specific humidity	Returns 0 in demo version.
SlingVWR	(DBT,WBT)-->VWR, Volumetric water ratio	Returns 0 in demo version.

Fluid Properties Utility for Use with Lee-Kesler Method

The current version of Lee-Kesler method support 467 different chemical compounds. You can use the utility software "C:\THERMOXL\fluidpro.exe" to view, edit or add new entries to our database. When you edit or add new entries, you should use the units mentioned in ellipses below. The database supports the following:

- Normal freezing point (Tfp, K)
- Norma boiling point (Tb, K at 1 atmosphere)
- Critical temperature (Tc, K)
- Critical pressure (Pc, bar)
- Critical specific volume (Vc, cm3/mol)
- Critical compressibility factor (Zc, no dimension)
- Pitzer's acentric factor (Omega, no dimension)
- Dipole moment (DipM, debyes)
- Standard enthalpy of formation (DELHF, J/mol)
- Standard Gibbs energy of formation (DELGF, J/mol)

Here is a screenshot of "fluidpro.exe".



List of Functions for Lee-Kesler method

These functions compute the thermodynamic properties of chemicals by using reduced pressure and temperature. When you activate LKXL.XLA, you have access to these functions. By clicking on

button in MS Excel a dialog over all function comes up. Select "**User Defined**" and you will have a list over all user defined functions. When you pick a function, a brief description of the function appears at the bottom of the dialog box. If you press "Next", Excel will continue with a dialog box that asks for the necessary inputs for the function. In case, you press "Enter" button, you should fill all the parameters with numbers, cell reference, variable's name and so on. These are the normal Excel functions behavior and are not specific for this program. If you need more help please see the on-line help of MS Excel or the user manual. The function names are compatible with the DLL version of the software. User who upgrade to this version from DLL version, will find several new functions. There are some simple rules that will help you to remember functions' names. Here is the complete list of functions:

Function	**Description**	**Comment**
LKPFT	(P,F)->T, reduced temperature	Returns 0 in demo version.
LKPHT	(P,H)->T, reduced temperature	Returns 0 in demo version.
LKPQF	(P,Q)->F, fugacity-pressure ratio	Returns 0 in demo version.
LKPQH	(P,Q)->H, residual enthalpy	Returns 0 in demo version.
LKPQS	(P,Q)->S, residual entropy	Returns 0 in demo version.
LKPQZ	(P,Q)->Z, compressibility factor	Returns 0 in demo version.
LKPST	(P,S)->T, reduced temperature	Returns 0 in demo version.
LKPZT	(P,Z)->T, reduced temperature	Returns 0 in demo version.
LKPT	**(P)->T, reduced saturation temperature**	**Should work in demo version.**
LKPTF	(P,T)->F, fugacity-pressure ratio	Returns 0 in demo version.
LKPTH	(P,T)->H, residual enthalpy	Returns 0 in demo version.
LKPTS	(P,T)->S, residual entropy	Returns 0 in demo version.
LKPTZ	(P,T)->Z, compressibility factor	Returns 0 in demo version.
LKTP	(T)->P, reduced saturation pressure	Returns 0 in demo version.
LKTQF	(T,Q)->F, fugacity-pressure ratio	Returns 0 in demo version.
LKTQH	(T,Q)->H, residual enthalpy	Returns 0 in demo version.
LKTQS	(T,Q)->S, residual entropy	Returns 0 in demo version.
LKTQZ	(T,Q)->Z, compressibility factor	Returns 0 in demo version.

Simple Rules to Remember Functions' Names

All functions for steam/water properties start with **STM** then follow abbreviations for inputs needed and at last the output. Some examples are **STMPTH** needs **P**, pressure and **T**, temperature to calculate **H**, specific enthalpy, **STMPHT** needs **P**, pressure and **H**, specific enthalpy and calculates **T**, temperature.

The same rule applies to functions for dry air, moist air and flue gases. Functions for dry and moist air start with **Air** and functions for flue gases start with **Flue**. All functions for dry/moist air need mc, moisture content. Therefore it has been omitted from the function's name. The same is with the flue gas functions. All of them require the volumetric or mole fraction of the gases. Functions for screen hygrometer start with **Screen** and functions for sling hygrometer start with **Sling** . These functions calculate **SH**, specific humidity, **RH**, relative humidity, **PS**, percentage saturation and **VWR**, volumetric water ratio.

The Lee-Kesler method functions start with **LK** then follow abbreviations for inputs needed and at last the output. All these functions need Pitzer's acentric factor as the last input. Some examples are **LKPTH** needs **P**, reduced pressure and **T**, reduced temperature and also acentric factor to calculate **H**, residual specific enthalpy, **LKPHT** needs **P**, reduced pressure and **H**, residual specific enthalpy, acentric factor and calculates **T**, reduced temperature.

Abbreviations Used for Function Names and Input/ Output Parameters

- Cp: Specific heat capacity at constant pressure
- Cv: Specific heat capacity at constant volume
- Dv: Dynamic viscosity
- F: Fugacity-pressure ratio
- Gamma: Ratio of Cp/Cv
- GC: Gas constant
- H: Specific enthalpy (residual specific enthalpy for Lee-Kesler method)
- mc: Moisture content
- MM: Molecular mass
- P: Pressure (reduced pressure for Lee-Kesler method)
- PS: Percentage saturation
- Q: Steam quality = dryness fraction = 1 - wetness fraction
- RH: Relative humidity
- S: Specific entropy (residual specific entropy for Lee-Kesler method)
- SH: Specific humidity = moisture content
- T: Temperature (reduced temperature in Lee-Kesler method)
- Tc: Thermal conductivity
- V: Specific volume
- VWR: Volumetric water ratio
- Z: Compressibility factor

Macro Development and Error Handling

You can view our function prototypes and VBA interface by selecting "Tool", "Macro", "Visual Basic Editor" (short cut ALT+F11). By developing your own macros you can speed up your calculations and also make your own dialog boxes for input/output. This is particularly true when you need several outputs with the same set of inputs.

Error handling/reporting for Steam/water functions

All functions return large negative numbers in case of error. No function returns a negative number less than **-1000** no matter what units are used. The returned values and reasons are:

- -1001: The pressure is outside the acceptable range specified in IFC formulation for Industrial use!

  0.01 bar < P < 1000 bar

- -1002: The temperature is outside the acceptable range specified in IFC formulation for Industrial use!

  0 C < T < 800 C

- -1003: Dryness fraction should be within the following limits:

  0.0= < Q < = 1.0

- -1004: Pressure of the wet steam may not be more than 221.0 bar (pressure at critical point is 221.2 bar) i.e.

  P <= 221.0 bar

- -1005: Temperature of the wet steam may not be more than 374.0 C (temperature at critical point is 374.15 C) i.e.

  T <= 374.0 C

- -1012: It is impossible to find a point with the specified pressure [P] and specific entropy [s]!
- -1013: It is impossible to find a point with the specified pressure [P] and specific volume [v]!
- -1014: It is impossible to find a point with the specified pressure [P] and specific enthalpy [h]!
- -1015: Inputs are not enough to determine the state of the steam or water. Pressure and temperature are too close to wet steam data.
- -1016: Pressure and temperature are too close to critical point.
- -1017: Specific volume is too small.

Error Handling/Reporting for Air and Flue Gas Functions

All functions return large negative numbers in case of error. No function returns a negative number less than **-20E+9** no matter what units are used. The returned values and reasons are:

- -21E+9: Moisture content, mc, is not acceptable!

0 =< mc < 0.30

- -22E+9: Volumetric compositions should be within the interval zero and one and the sum must be one.
- -23E+9: Temperature should be within the following limits:

-40 C < T < 1500 C

- -24E+9: It is impossible to find a temperature with the specified specific enthalpy.
- -25E+9: It is impossible to find a temperature with the specified specific entropy.
- -26E+9: It is impossible to find a temperature with the specified specific heat capacity.
- -27E+9: The wet bulb temperature is limited to:

-40 C < T < 70 C

- -28E+9: The following condition should be satisfied:

DryBulbT >= WetBulbT

- -29E+9: The set of values for dry and wet bulb temperatures are not possible!
- -30E+9: Pressure is outside the acceptable range:

1. bar < P < 20 bar

- -31E+9: Gas constant is too small.

Error Handling/Reporting for Lee-Kesler Functions

All functions return large negative numbers in case of error. No function returns a negative number less than -**2000**. No matter what units are used. The returned values and reasons are:

- -2001: The pressure is outside the acceptable range!

  0.01 < Pr < 10

  Pr = Reduced pressure = P/Pcr

  Pcr = Critical pressure

  P = Pressure

- -2002: The temperature is outside the acceptable range!

  0.3 < Tr < 4.0

  Tr = Reduced temperature = T/Tcr

  Tcr = Critical temperature

  T = Temperature

- -2003: Dryness fraction should be within the following limits:

  0.0= < Q < = 1.0

- -2004: Pressure of wet vapor may not be more than Pcr i.e.

  Pr < = 1.0

- -2005: Temperature of wet vapor may not be more than Tcr i.e.

  Tr < = 1.0

- -2012: It is impossible to find a point with the specified reduced pressure [Pr] and reduced specified entropy [sr]!
- -2013: It is impossible to find a point with the specified reduced pressure [Pr] and compressibility factor [Z]!

  Z = (V * P) / (R * T)

  V = Specific volume

R = Gas Constant = 8.3144 J/(mol.K) = 10.732 psia.ft2/(lb-mol.R)

- -2014: It is impossible to find a point with the specified reduced pressure [Pr] and reduced specific enthalpy [h]!
- -2015: Inputs are not enough to determine the state of the fluid. Pressure and temperature are too close to wet vapor data.
- -2016: It is impossible to find a point with the specified reduced pressure [Pr] and reduced fugacity-pressure ratio [f]!
- -2020: Acentric factor is out of acceptable range.

$-0.5 < Af < 2.0$

VBA Function Prototypes for Steam and Water Properties

You can view the content of “STMXL.XLA” by using short cut ALT+F11. The function prototypes are:

Private Declare Sub VBASATP Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByRef T#, ByRef vf#, ByRef vg#, ByRef hf#, ByRef hg#, ByRef sf#, ByRef sg#, ByRef ErrorCode%)

Private Declare Sub VBASATT Lib "C:\THERMOXL\TUXL.DLL" (ByVal T#, ByRef P#, ByRef vf#, ByRef vg#, ByRef hf#, ByRef hg#, ByRef sf#, ByRef sg#, ByRef ErrorCode%)

Private Declare Sub VBASUPERHEATED Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal T#, ByRef V#, ByRef H#, ByRef S#, ByRef Q#, ByRef ErrorCode%)

Private Declare Sub VBAPS Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal S#, ByRef T#, ByRef V#, ByRef H#, ByRef Q#, ByRef ErrorCode%)

Private Declare Sub VBAPH Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal H#, ByRef T#, ByRef V#, ByRef S#, ByRef Q#, ByRef ErrorCode%)

Private Declare Sub VBAPV Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal V#, ByRef T#, ByRef H#, ByRef S#, ByRef Q#, ByRef ErrorCode%)

Private Declare Sub CONDUCTIVITY Lib "C:\THERMOXL\TUXL.DLL" (ByVal V#, ByVal T#, ByRef L#, ByRef ErrorCode%)

Private Declare Sub VISCOSITY Lib "C:\THERMOXL\TUXL.DLL" (ByVal V#, ByVal T#, ByRef mi#, ByRef ErrorCode%)

Private Declare Sub VBACP Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal T#, ByRef Cp#, ByRef ErrorCode%)

Private Declare Sub VBACP_T0 Lib "C:\THERMOXL\TUXL.DLL" (ByVal T#, ByRef Cp#, ByRef ErrorCode%)

Private Declare Sub VBACP_T1 Lib "C:\THERMOXL\TUXL.DLL" (ByVal T#, ByRef Cp#, ByRef ErrorCode%)

Private Declare Sub STATEOFREGSTM Lib "C:\THERMOXL\TUXL.DLL" (ByRef State%)

VBA Function Prototypes for Air and Flue Gas Properties

You can view the content of “AIRXL.XLA” by using short cut ALT+F11. The function prototypes are:

Private Declare Sub VBAEGGC Lib "C:\THERMOXL\TUXL.DLL" (ByVal N2#, ByVal O2#, ByVal CO2#, ByVal Ar#, ByVal H2O#, ByVal SO2#, ByRef GC#, ByRef ErrorCode%)

Private Declare Sub VBAEGMM Lib "C:\THERMOXL\TUXL.DLL" (ByVal N2#, ByVal O2#, ByVal CO2#, ByVal Ar#, ByVal H2O#, ByVal SO2#, ByRef MM#, ByRef ErrorCode%)

Private Declare Sub VBAEGT Lib "C:\THERMOXL\TUXL.DLL" (ByVal N2#, ByVal O2#, ByVal CO2#, ByVal Ar#, ByVal H2O#, ByVal SO2#, ByVal T#, ByRef H#, ByRef Cp#, ByRef Cv#, ByRef Gam#, ByRef S#, ByRef ErrorCode%)

Private Declare Sub VBAEGHT Lib "C:\THERMOXL\TUXL.DLL" (ByVal N2#, ByVal O2#, ByVal CO2#, ByVal Ar#, ByVal H2O#, ByVal SO2#, ByVal H#, ByRef T#, ByRef ErrorCode%)

Private Declare Sub VBAEGST Lib "C:\THERMOXL\TUXL.DLL" (ByVal N2#, ByVal O2#, ByVal CO2#, ByVal Ar#, ByVal H2O#, ByVal SO2#, ByVal S#, ByRef T#, ByRef ErrorCode%)

Private Declare Sub VBAEGCPT Lib "C:\THERMOXL\TUXL.DLL" (ByVal N2#, ByVal O2#, ByVal CO2#, ByVal Ar#, ByVal H2O#, ByVal SO2#, ByVal Cp#, ByRef T#, ByRef ErrorCode%)

Private Declare Sub VBAEGTC Lib "C:\THERMOXL\TUXL.DLL" (ByVal N2#, ByVal O2#, ByVal CO2#, ByVal Ar#, ByVal H2O#, ByVal SO2#, ByVal T#, ByVal P#, ByRef Tc#, ByRef ErrorCode%)

Private Declare Sub VBAEGDV Lib "C:\THERMOXL\TUXL.DLL" (ByVal N2#, ByVal O2#, ByVal CO2#, ByVal Ar#, ByVal H2O#, ByVal SO2#, ByVal T#, ByVal P#, ByRef Dv#, ByRef ErrorCode%)

Private Declare Sub VBAEGDPT Lib "C:\THERMOXL\TUXL.DLL" (ByVal N2#, ByVal O2#, ByVal CO2#, ByVal Ar#, ByVal H2O#, ByVal SO2#, ByVal P#, ByRef Dpt#, ByRef ErrorCode%)

Private Declare Sub VBASLINGSH Lib "C:\THERMOXL\TUXL.DLL" (ByVal DryBulbT#, ByVal WetBulbT#, ByRef SH#, ByRef ErrorCode%)

Private Declare Sub VBASLINGPS Lib "C:\THERMOXL\TUXL.DLL" (ByVal DryBulbT#, ByVal WetBulbT#, ByRef PS#, ByRef ErrorCode%)

Private Declare Sub VBASLINGRH Lib "C:\THERMOXL\TUXL.DLL" (ByVal DryBulbT#, ByVal WetBulbT#, ByRef RH#, ByRef ErrorCode%)

Private Declare Sub VBASLINGVWR Lib "C:\THERMOXL\TUXL.DLL" (ByVal DryBulbT#, ByVal WetBulbT#, ByRef VWR#, ByRef ErrorCode%)

Private Declare Sub VBASCREENSH Lib "C:\THERMOXL\TUXL.DLL" (ByVal DryBulbT#, ByVal WetBulbT#, ByRef SH#, ByRef ErrorCode%)

Private Declare Sub VBASCREENPS Lib "C:\THERMOXL\TUXL.DLL" (ByVal DryBulbT#, ByVal WetBulbT#, ByRef PS#, ByRef ErrorCode%)

Private Declare Sub VBASCREENRH Lib "C:\THERMOXL\TUXL.DLL" (ByVal DryBulbT#, ByVal WetBulbT#, ByRef RH#, ByRef ErrorCode%)

Private Declare Sub VBASCREENVWR Lib "C:\THERMOXL\TUXL.DLL" (ByVal DryBulbT#, ByVal WetBulbT#, ByRef VWR#, ByRef ErrorCode%)

Private Declare Sub VBAAIRGC Lib "C:\THERMOXL\TUXL.DLL" (ByVal mc#, ByRef GC#, ByRef ErrorCode%)

Private Declare Sub VBAAIRMM Lib "C:\THERMOXL\TUXL.DLL" (ByVal mc#, ByRef MM#, ByRef ErrorCode%)

Private Declare Sub VBAAIRT Lib "C:\THERMOXL\TUXL.DLL" (ByVal mc#, ByVal T#, ByRef H#, ByRef Cp#, ByRef Cv#, ByRef Gam#, ByRef S#, ByRef ErrorCode%)

Private Declare Sub VBAAIRHT Lib "C:\THERMOXL\TUXL.DLL" (ByVal mc#, ByVal H#, ByRef T#, ByRef ErrorCode%)

Private Declare Sub VBAAIRCPT Lib "C:\THERMOXL\TUXL.DLL" (ByVal mc#, ByVal Cp#, ByRef T#, ByRef ErrorCode%)

Private Declare Sub VBAAIRST Lib "C:\THERMOXL\TUXL.DLL" (ByVal mc#, ByVal S#, ByRef T#, ByRef ErrorCode%)

Private Declare Sub VBAAIRTC Lib "C:\THERMOXL\TUXL.DLL" (ByVal mc#, ByVal T#, ByVal P#, ByRef Tc#, ByRef ErrorCode%)

Private Declare Sub VBAAIRDV Lib "C:\THERMOXL\TUXL.DLL" (ByVal mc#, ByVal T#, ByVal P#, ByRef Dv#, ByRef ErrorCode%)

Private Declare Sub VBAAIRDPT Lib "C:\THERMOXL\TUXL.DLL" (ByVal mc#, ByVal P#, ByRef Dpt#, ByRef ErrorCode%)

Private Declare Sub VBADENSITY Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal GC#, ByVal T#, ByRef Ro#, ByRef ErrorCode%)

Private Declare Sub VBAADJUSTS Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal GC#, ByVal S#, ByRef S0#, ByRef ErrorCode%)

Private Declare Sub VBAADJUSTS0 Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal GC#, ByVal S0#, ByRef S#, ByRef ErrorCode%)

Private Declare Sub STATEOFREGAIR Lib "C:\THERMOXL\TUXL.DLL" (ByRef State%)

VBA Function Prototypes for Lee-Kesler Method

You can view the content of “LKXL.XLA” by using short cut ALT+F11. The function prototypes are:

Private Declare Sub LEKEPHT Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal H#, ByVal Omega#, ByRef T#, ByRef ErrorCode%)

Private Declare Sub LEKEPST Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal S#, ByVal Omega#, ByRef T#, ByRef ErrorCode%)

Private Declare Sub LEKEPFT Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal F#, ByVal Omega#, ByRef T#, ByRef ErrorCode%)

Private Declare Sub LEKEPZT Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal Z#, ByVal Omega#, ByVal SolutionIndex%, ByRef T#, ByRef ErrorCode%)

Private Declare Sub LEKEPTZ Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal T#, ByVal Omega#, ByRef Z#, ByRef ErrorCode%)

Private Declare Sub LEKEPQZ Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal Q#, ByVal Omega#, ByRef Z#, ByRef ErrorCode%)

Private Declare Sub LEKETQZ Lib "C:\THERMOXL\TUXL.DLL" (ByVal T#, ByVal Q#, ByVal Omega#, ByRef Z#, ByRef ErrorCode%)

Private Declare Sub LEKEPTH Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal T#, ByVal Omega#, ByRef H#, ByRef ErrorCode%)

Private Declare Sub LEKEPQH Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal Q#, ByVal Omega#, ByRef H#, ByRef ErrorCode%)

Private Declare Sub LEKETQH Lib "C:\THERMOXL\TUXL.DLL" (ByVal T#, ByVal Q#, ByVal Omega#, ByRef H#, ByRef ErrorCode%)

Private Declare Sub LEKEPTS Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal T#, ByVal Omega#, ByRef S#, ByRef ErrorCode%)

Private Declare Sub LEKEPQS Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal Q#, ByVal Omega#, ByRef S#, ByRef ErrorCode%)

Private Declare Sub LEKETQS Lib "C:\THERMOXL\TUXL.DLL" (ByVal T#, ByVal Q#, ByVal Omega#, ByRef S#, ByRef ErrorCode%)

Private Declare Sub LEKEPTF Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal T#, ByVal Omega#, ByRef F#, ByRef ErrorCode%)

Private Declare Sub LEKEPQF Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal Q#, ByVal Omega#, ByRef F#, ByRef ErrorCode%)

Private Declare Sub LEKETQF Lib "C:\THERMOXL\TUXL.DLL" (ByVal T#, ByVal Q#, ByVal Omega#, ByRef F#, ByRef ErrorCode%)

Private Declare Sub LEKEPT Lib "C:\THERMOXL\TUXL.DLL" (ByVal P#, ByVal Omega#, ByRef Tsat#, ByRef ErrorCode%)

Private Declare Sub LEKETP Lib "C:\THERMOXL\TUXL.DLL" (ByVal T#, ByVal Omega#, ByRef Psat#, ByRef ErrorCode%)

Private Declare Sub STATEOFREGLK Lib "C:\THERMOXL\TUXL.DLL" (ByRef State%)

List of Worksheets with Function Calls

You should be able to open these files on all MS Excel versions from 97 and higher. The files are located in folder “C:\THERMOXL”

File Location	**Brief Description**
EXAMPLE-main.xls	How to Activate different add-ins
EXAMPLE-Air and Flue Gas Properties.xls	List of all functions, including 7 demo functions.
EXAMPLE-Steam and Water Properties.xls	List of all functions, including 2 demo functions.
EXAMPLE-LeeKesler.xls	List of all functions, including 1 demo functions.
Example - Unit Conversion.xls	How to obtain the text string for used units.
Chemical Compound Properties.xls	Free data base for 467 different chemicals with information about, normal freezing point, normal boiling point, critical temperature, critical pressure, critical specific volume, critical compressibility factor, Pitzer's acentric factor, dipole moment, standard enthalpy of formation, standard Gibbs energy of formation. *Attention! Please verify the information in this file with a second source for important applications.*

After activation of different add-ins, you should be able to use the demo functions in each worksheet without any problems. The other functions should return zero.

“Example - Unit Conversion.xls” and “Chemical Compound Properties.xls” should be fully functional.

Sample Files

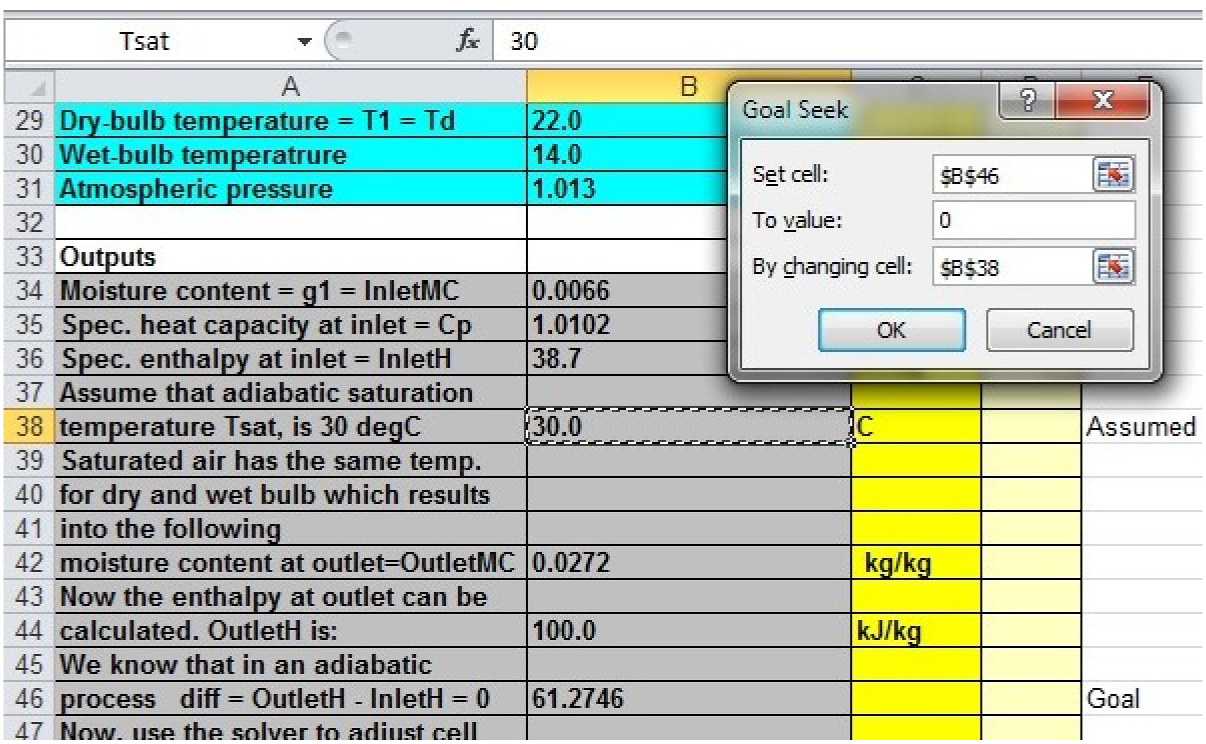
Adiabatic Humidification with Air Washer.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder "C:\THERMOXL". The calculations are straight forward. The output of registered version can be seen in Appendix A.

Adiabatic Saturation Temperature of Air.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder "C:\THERMOXL". In order to calculate the adiabatic saturation temperature you need to make and assumption for the value of cell **B38** and use Excel "Goal Seek" to change this value till the value of **B46** is zero.

Goal Seek (Excel 2010): In order to reach "Goal Seek", first click on "Data" tab. Then click on "What-If Analysis" and last select "Goal Seek …". "Goal seek is supported under Excel 97-2003 and later versions.



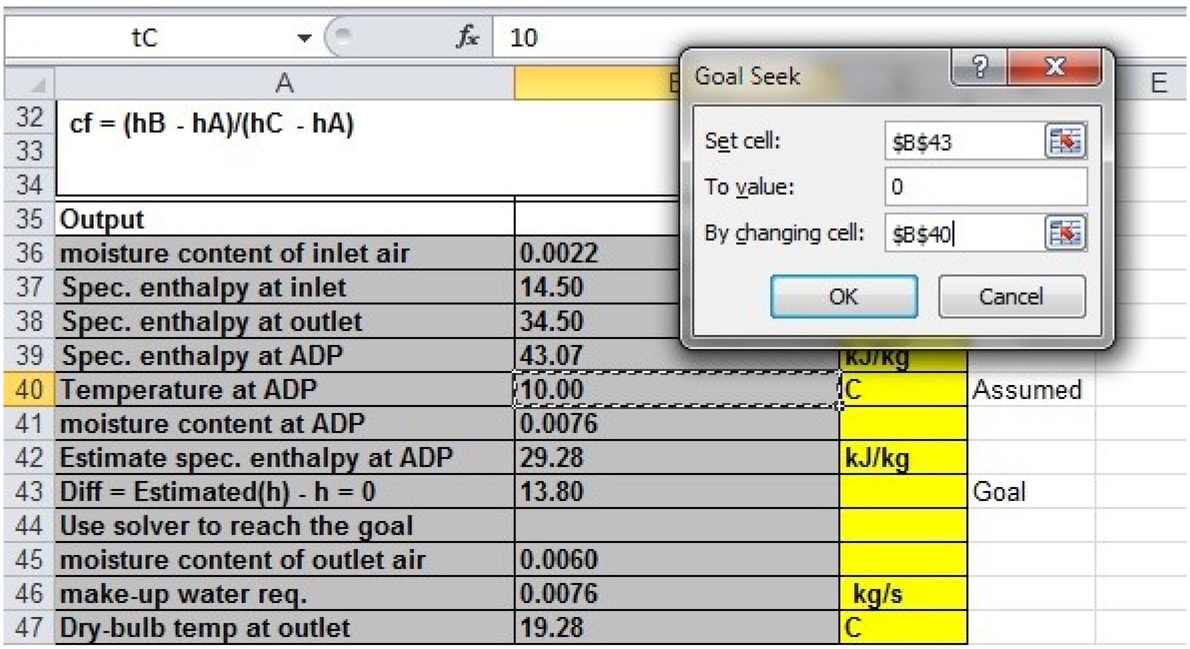
The initial value of B38 was 30C (assumed) and the final value 13.8C. The initial value of B46 was 61.27 kJ/kg and final value 0.

The output of registered version can be seen in Appendix B.

Air Washer with Heating of Spray Water.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder “C:\THERMOXL”. In order to calculate the apparatus dew-point (ADP) you need to make and assumption for the value of cell **B40** and use Excel “Goal Seek” to change this value till the value of **B43** is zero.

Goal Seek (Excel 2010): In order to reach “Goal Seek”, first click on “Data” tab. Then click on “What-If Analysis” and last select “Goal Seek …”. “Goal seek is supported under Excel 97-2003 and later versions.



The initial value of **B40** was 10C (assumed) and the final value 15.38C. The initial value of **B43** was 13.8 kJ/kg and final value 0.

The output of registered version can be seen in Appendix C.

Calculating Humid Air Data.xls

Not all the outputs calculated in this worksheet need a registered version. The file is located in folder “C:\THERMOXL”. The output of registered version can be seen in Appendix D.

Closed-feed Heater.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder "C:\THERMOXL". The calculations are straight forward. The output of registered version can be seen in Appendix E.

Coal Combustion.xls

Most outputs calculated in this worksheet do not need a registered version. The file is located in folder "C:\THERMOXL". The calculations are straight forward. The output of registered version can be seen in Appendix F.

Combustion of Biomass Fuel.xls

Most outputs calculated in this worksheet do not need a registered version. The file is located in folder "C:\THERMOXL". The calculations are straight forward. The output of registered version can be seen in Appendix G.

Combustion of Fossil Fuels.xls

Most outputs calculated in this worksheet do not need a registered version. The file is located in folder "C:\THERMOXL". The calculations are straight forward. The output of registered version can be seen in Appendix H.

Compression Process Calculations.xls

This worksheet shows the calculations for a single stage compressor. All the outputs calculated in this worksheet need a registered version. The file is located in folder "C:\THERMOXL". The calculations are straight forward. The output of registered version can be seen in Appendix I.

Condenser Design.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder "C:\THERMOXL". The calculations are straight forward. The output of registered version can be seen in Appendix J.

Cooling Tower.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder “C:\THERMOXL”. The calculations are straight forward. The output of registered version can be seen in Appendix K.

Direct Steam Injection - Steam Humidifier.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder “C:\THERMOXL”. The calculations are straight forward. The output of registered version can be seen in Appendix L.

Expansion Process - Gas Turbine.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder “C:\THERMOXL”. The calculations are straight forward. The output of registered version can be seen in Appendix M.

Feed Heater.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder “C:\THERMOXL”. The calculations are straight forward. The output of registered version can be seen in Appendix N.

Lkdemo1.xls, Lkdemo2.xls, Lkdemo3.xls, Lkdemo4.xls and Lkdemo5.xls

These five examples show how Lee-Kesler method can be used. Most of the outputs calculated in these worksheets need a registered version. The files are located in folder “C:\THERMOXL”. The calculations are straight forward. The output of registered version can be seen in Appendix O1 thru Appendix O5.

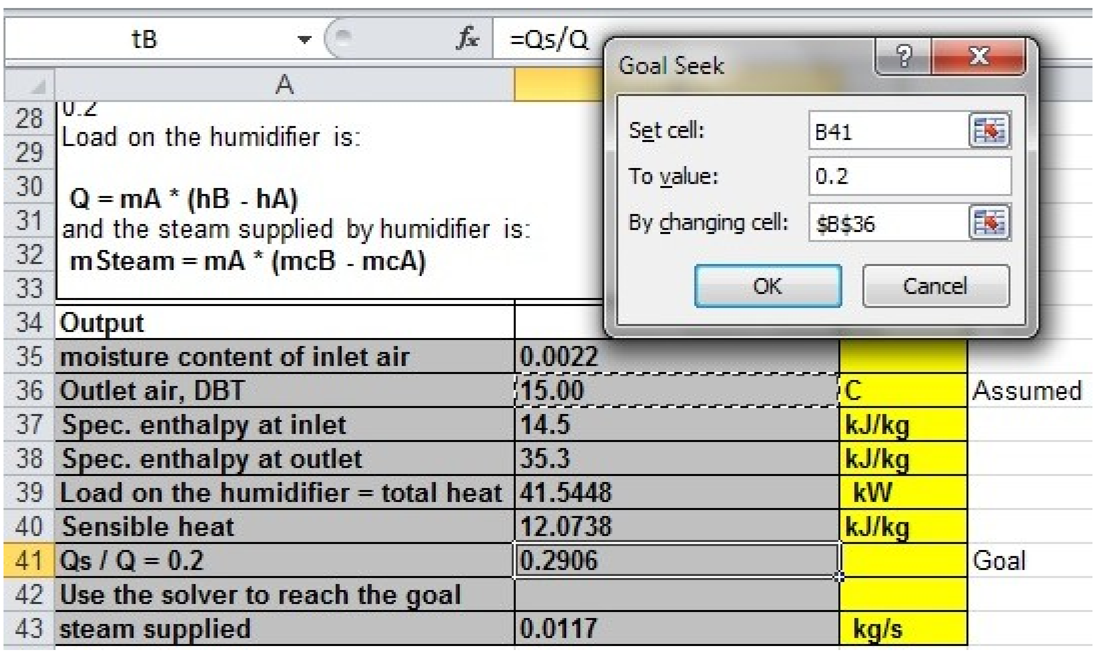
Mixing of Two Air Streams.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder “C:\THERMOXL”. The calculations are straight forward. The output of registered version can be seen in Appendix P.

Pan Steam Humidifier.xls

Most of the outputs calculated in this worksheet need a registered version. The file is located in folder “C:\THERMOXL”. In order to calculate the ratio of sensible heat to total heat (Qs/Q) you need to make an assumption for the value of cell **B36** and use Excel “Goal Seek” to change this value till the value of **B41** is 0.20.

Goal Seek (Excel 2010): In order to reach “Goal Seek”, first click on “Data” tab. Then click on “What-If Analysis” and last select “Goal Seek …”. “Goal seek is supported under Excel 97-2003 and later versions.



The initial value of **B36** was 15C (assumed) and the final value 12.66C. The initial value of **B41** was 0.29 and final value 0.20.

The output of registered version can be seen in Appendix Q.

Pump.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder “C:\THERMOXL”. The calculations are straight forward. The output of registered version can be seen in Appendix R.

Regenerative Steam Cycle.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder “C:\THERMOXL”. The calculations are straight forward. The output of registered version can be seen in Appendix S.

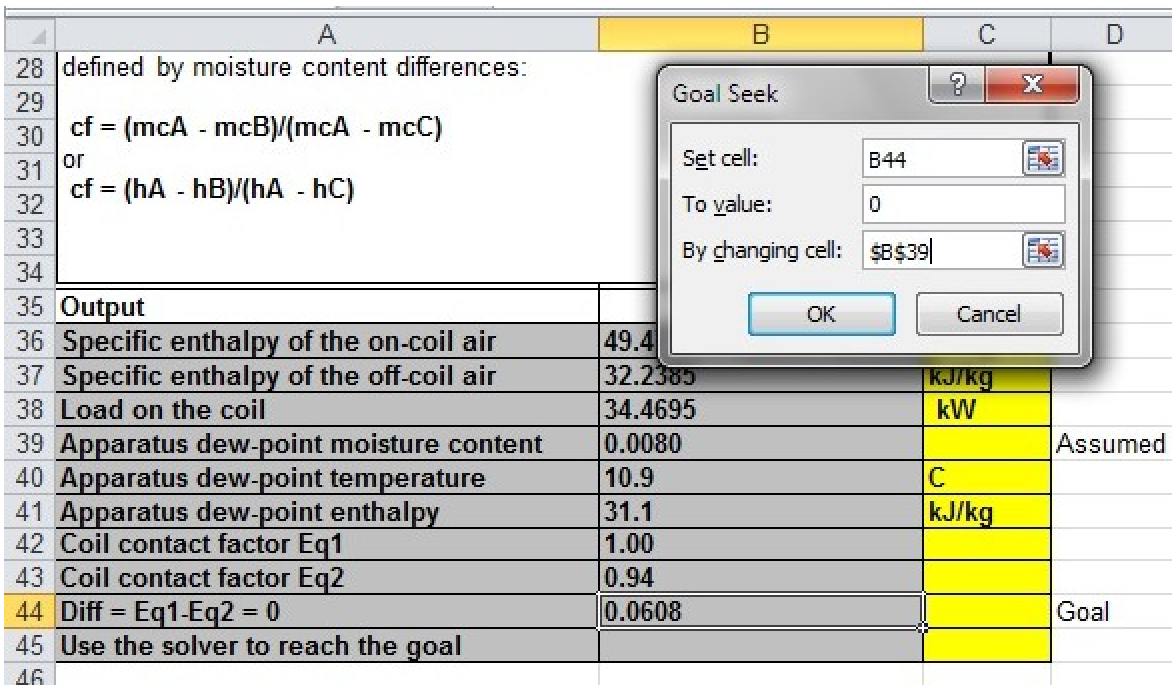
Sensible Cooling Process.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder “C:\THERMOXL”. The calculations are straight forward. The output of registered version can be seen in Appendix T.

Sensible Cooling with Dehumidification.xls

Most of the outputs calculated in this worksheet need a registered version. The file is located in folder “C:\THERMOXL”. Apparatus dew-point moisture content (cell **B39**) should make the calculated value of Eq1 and Eq2 the same or in other words the difference (cell **B44**) should be zero.

Goal Seek (Excel 2010): In order to reach “Goal Seek”, first click on “Data” tab. Then click on “What-If Analysis” and last select “Goal Seek …”. “Goal seek is supported under Excel 97-2003 and later versions.



The initial value of **B39** was 0.008 (assumed) and the final value 0.0077. The initial value of **B44** was 0.0608 and final value 0.00.

The output of registered version can be seen in Appendix U.

Sensible Heating Process.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder “C:\THERMOXL”. The calculations are straight forward. The output of registered version can be seen in Appendix V.

Steam Turbine.xls

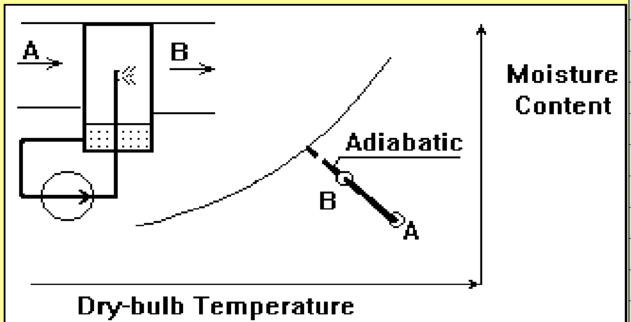
All the outputs calculated in this worksheet need a registered version. The file is located in folder "C:\THERMOXL". The calculations are straight forward. The output of registered version can be seen in Appendix W.

Valve - Throttling Process.xls

All the outputs calculated in this worksheet need a registered version. The file is located in folder "C:\THERMOXL". The calculations are straight forward. The output of registered version can be seen in Appendix X.

Appendix A

In an air conditioning plant, air flow rate of 2 kg/s passes through a spray water humidifier with a contact factor 0.7. Determine the moisture content and temperature of the air leaving the humidifier and the amout of make-up water needed. The dry and wet-bulb temperature of the inlet air are 25 C and 15 C respectively.



Inputs		Units
Inlet air, DBT	24.00	C
Inlet air, WBT	15.00	C
Inlet air, mass flow rate	2.00	kg/s
Contact factor of the humidifier	0.70	
Atmospheric pressure	1.01	bar

The contact factor of a humidifier is defined as the efficiency for humidification. A 100% efficient humidifier will bring the moisture content of the air to the saturation moisture content at the apparatus dew-point, mcC. The contact factor of the humidifier can be defined by the moisture content differences:

cf = (mcB - mcA)/(mcC - mcA)
or
cf = (hB - hA)/(hC - hA)

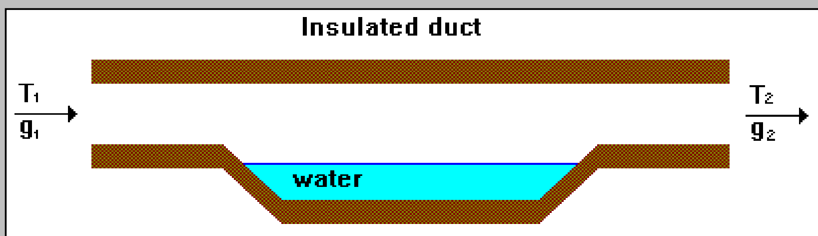
Output		
moisture content of inlet air	0.0068	
moisture content at ADP	0.0106	
moisture content of outlet air	0.0095	
make-up water req.	0.0054	kg/s
Spec. enthalpy at inlet	41.4	kJ/kg
Spec. enthalpy at ADP	42.0	kJ/kg
Spec. enthalpy at outlet	41.8	kJ/kg
Dry-bulb temp at outlet	17.70	C

Appendix B

Determine the adiabatic saturation temperature of air at the

following conditions:
dry-bulb temperature 22 degC
wet-bulb temperature (sling) 14 degC

An adiabatic process is defined as a process in which no external heat enters or leaves the system under consideration.
Adiabatic humidification process: Air is flowing through a perfectly insulated duct with an open water tank in the bottom of it. If the tank is infinitely long, the air at the outlet will be 100% saturated.
Inlet: dry-bulb temperature T1 and moisture content g1
Outlet: dry-bulb temperature T2 and moisture content g2
We may write: **h1 = h2** or **Sensible heat loss = Latent heat gain** i.e.
Cp * (T1 - T2) = Hfg * (g2 - g1)

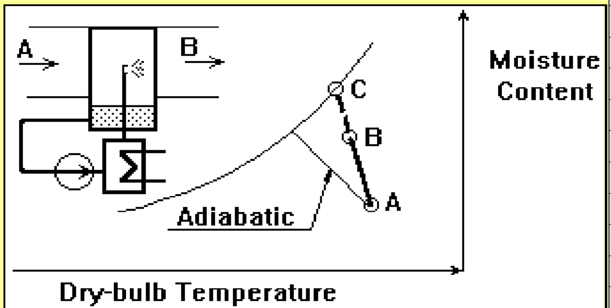


Inputs		Units	Error ?	
Dry-bulb temperature = T1 = Td	22.0	C		
Wet-bulb tempertrure	14.0	C		
Atmospheric pressure	1.013	C		
Outputs				
Moisture content = g1 = InletMC	0.0066	kg/kg		
Spec. heat capacity at inlet = Cp	1.0102	kJ/(kg.K)		
Spec. enthalpy at inlet = InletH	38.7	kJ/kg		
Assume that adiabatic saturation				
temperature Tsat, is 30 degC	13.8	C		Assumed
Saturated air has the same temp.				
for dry and wet bulb which results				
into the following				
moisture content at outlet=OutletMC	0.0098	kg/kg		
Now the enthalpy at outlet can be				
calculated. OutletH is:	38.7	kJ/kg		
We know that in an adiabatic				
process diff = OutletH - InletH = 0	0.0001			Goal
Now, use the solver to adjust cell				
Tsat, until the goal cell				
diff is zero.				
Adiabatic Saturation Temp. =Tsat =	13.8	C		

Taftan Data
Email: support@taftan.com

Appendix C

In an air conditioning plant, air flow rate of 2 kg/s passes through a spray water humidifier with a contact factor 0.7. The calorifier provides 40 kW. Determine the moisture content and temperature of the air leaving the humidifier and the amout of make-up water needed. The dry and wet-bulb temperature of the inlet air are 9 C and 3 C respectively.



Inputs		Units
Inlet air, DBT	9.00	C
Inlet air, WBT	3.00	C
Inlet air, mass flow rate	2.00	kg/s
Contact factor of the humidifier	0.70	
Heat provided by the calorifier	40.00	kW
Atmospheric pressure	1.01	bar

The contact factor of a humidifier is defined as the efficiency for humidification. A 100% efficient humidifier will bring the moisture content of the air to the saturation moisture content at the apparatus dew-point, mcC. The contact factor of the humidifier can be defined by the moisture content differences:

cf = (mcB - mcA)/(mcC - mcA)

or

cf = (hB - hA)/(hC - hA)

Output			
moisture content of inlet air	0.0022		
Spec. enthalpy at inlet	14.50	kJ/kg	
Spec. enthalpy at outlet	34.50	kJ/kg	
Spec. enthalpy at ADP	43.07	kJ/kg	
Temperature at ADP	15.38	C	Assumed
moisture content at ADP	0.0109		
Estimate spec. enthalpy at ADP	43.07	kJ/kg	
Diff = Estimated(h) - h = 0	0.0001		Goal
Use solver to reach the goal			
moisture content of outlet air	0.0083		
make-up water req.	0.0122	kg/s	
Dry-bulb temp at outlet	13.50	C	

Taftan Data
Email: support@taftan.com

Appendix D

Determine the vapor pressure, moisture content, percentage saturation, relative humidity, specific enthalpy, specific heat capacity, specific entropy and density for air with the following conditions:

dry-bulb temperature 22 degC
wet-bulb temperature (sling) 14 degC

Inputs		Units	Error ?
Dry-bulb temperature	22.0	C	
Wet-bulb tempertrure	14.0	C	
Atmospheric pressure	1.013	bar	
Outputs			
Moisture content	0.0066		
Percentage saturation	0.3982		
Relative humidity	0.4003		
Gas Constant	0.2882	kJ/(kg.K)	
Specific heat capacity	1.0102	kJ/(kg.K)	
Specific enthalpy	38.7042	kJ/kg	
Specific entropy	0.0782	kJ/(kg.K)	
Density	0.0168	kg/m3	
Molecular mass	28.8525	kg/kmol	
Vapor pressure=Patm*mc/(mc+0.622)	0.0106	bar	

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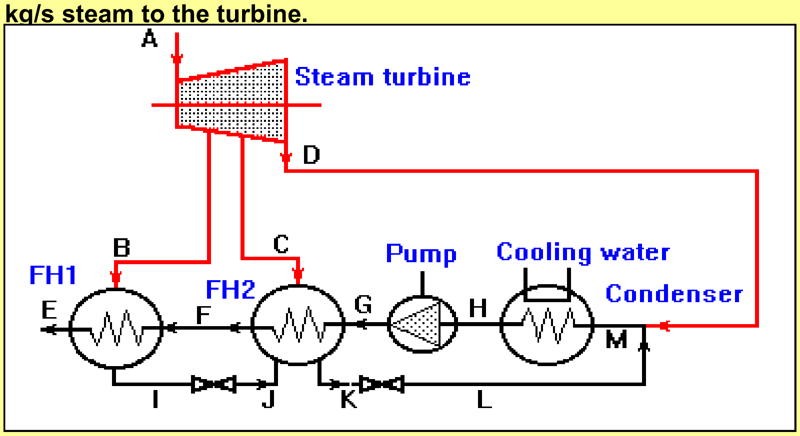
Appendix E

A regenerative steam cycle uses two closed-feed heaters. Determine the amount of steam bled at each stage. It is known that:
pB=10 bar, hB=3033 kJ/kg, pC=1.0 bar, hC=2590 kJ/kg, pG=40 bar, hG=112 kJ/kg
Boiler supplies 10 kg/s steam to the turbine.



Inputs		Units	Error ?
Spec. enthalpy at B	3033.00	kJ/kg	
Spec. enthalpy at C	2590.00	kJ/kg	
Spec. enthalpy at G	112.00	kJ/kg	
Pressure at B	10.00	bar	
Pressure at C	1.00	bar	
Pressure at G	40.00	bar	
Mass flow through the system	10.00	kg/s	
Outputs			
For the throttling process, I-J			
hE = hI = hJ	762.61	kJ/kg	
For the throttling process, K-L			
hF = hK = hL	417.51	kJ/kg	
Energy balance on FH1 gives, mB	1.52	kg/s	
Energy balance on FH2 gives, mC	1.16	kg/s	

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Appendix F

Dry anthracite with the following composition by mass:

C 90%; H 3%; O 2%; N 1%; S 1%; ash 3%

has been burned in a boiler, when 150% excess air is supplied.
Combustion efficiency is 0.75 Calculate:

1- the stoichiometric air-to-fuel (A/F) ratio
2- the A/F ratio
3- analysis of combustion products (dry and wet)
4- temperature of exhaust gases

Air is supplied at atmospheric pressure and 18 C with 0.008 specific humidity. The fuel has an average temperature of 35 C when enters the boiler. The net calorific value of the fuel at 15 C is 33 500 kJ/kg The specific heat capacity of fuel is 3.2 kJ/kg,K.

Combustion Equations

Combustion equation for coal:

C + O2 => CO2 (12 kg C)+(32 kg O) => (34 kg CO2)

Combustion equation for hydrogen:

2 H2 + O2 => 2 H2O (4 kg H)+(32 kg O) => (36 kg H2O)

Combustion equation for sulphur:

S + O2 => SO2 (32 kg S) + (32 kg O) => (64 kg SO2)

Fuel Analysis			
Constituent	**Mass fraction**	**Required oxygen**	**Product mass**
		kg/kg fuel	**kg/kg fuel**
Carbon	0.900	2.400	3.300
Hydrogen	0.030	0.240	0.270
Oxygen	0.020	-0.020	0.000
Nitrogen	0.010	0.000	0.010
Sulphur	0.010	0.010	0.020
Ash	0.030	0.000	0.030
	1.000	2.630	3.630
Analysis of Supplied Air			
Specific Humidity	0.008		
Composition by mass			
Constituent	**Dry Air**	**Humid Air**	
N2	0.76280	0.75670	
O2	0.23290	0.23104	
CO2	0.00300	0.00298	
Ar	0.00130	0.00129	
H2O	0.00000	0.00800	
SO2	0.00000	0.00000	
	1.00000	**1.00000**	

Combustion of coal

Air required per kg of fuel	11.38	Stoichiometric A/F ratio	kg/kg
Excess Air	1.5		
Actual A/F ratio kg/kg	28.45867		
Exhaust Gases		**Wet Mass**	**Dry Mass**
Constituent	**Mass**	**Composition**	**Composition**
N2	21.54461	0.73210	0.74469
O2	3.94500	0.13405	0.13636
CO2	3.38469	0.11501	0.11699
Ar	0.03670	0.00125	0.00127
H2O	0.49767	0.01691	0.00000
SO2	0.02000	0.00068	0.00069
	29.42867	**1.00000**	**1.00000**
Exhaust Gases			**Volume**
Constituent	**Kg/kmol**	**Mole Fraction**	**Composition**
N2	28	0.02615	0.77058
O2	32	0.00419	0.12346
CO2	44	0.00261	0.07704
Ar	40	0.00003	0.00092
H2O	18	0.00094	0.02769
SO2	64	0.00001	0.00031
		0.03393	1.00000
Mass balance			
Fuel	1.00000		
Supplied Air	28.45867		
	29.45867		
Exhaust Gases	29.42867		
Ash	0.03000		
	29.45867		
Supplied Air Temp.	18	**C**	
Fuel Cp	3.2	**kJ/(kg.K)**	
Net Calorific Value	33500	**kJ/kg**	
Combustion efficiency	0.75		
	Enthalpy	**Mass Flow**	**m*h**
	kJ/kg	**kg/s**	**kJ/s**
Supplied Air	38.31	28.46	1090.14
Fuel	64.00	1.00	64.00
Fuel Energy Supplied	33500.00	1.00	25125.00
			26279.14
Exhaust Gases	892.07		
Exhaust Gases Temp	774.	**C**	

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Appendix G

A biomass fuel with the following composition by mass:

C 54%; H 22%; O 12%; N 4%; S 1.3%; ash 6.7%
C1, percentage carbon on the dry ash-free basis 17%
has been burned in a boiler, when 150% excess air is supplied.
Combustion efficiency is 0.75 Calculate:

1- the stoichiometric air-to-fuel (A/F) ratio
2- the A/F ratio
3- analysis of combustion products (dry and wet)
4- temperature of exhaust gases

Air is supplied at atmospheric pressure and 18 C with 0.008 specific humidity. The fuel has an average temperature of 35 C when enters the boiler. Use Vondracek formula to estimate the net calorific value of the fuel.The specific heat capacity of fuel is 3.2 kJ/kg,K.

Combustion Equations

Combustion equation for coal:

C + O2 => CO2 (12 kg C)+(32 kg O) => (34 kg CO2)

Combustion equation for hydrogen:

2 H2 + O2 => 2 H2O (4 kg H)+(32 kg O) => (36 kg H2O)

Combustion equation for sulphur:

S + O2 => SO2 (32 kg S) + (32 kg O) => (64 kg SO2)

Fuel Analysis			
Constituent	**Mass fraction**	**Required oxygen**	**Product mass**
		kg/kg fuel	**kg/kg fuel**
Carbon	0.540	1.440	1.980
Hydrogen	0.220	1.760	1.980
Oxygen	0.120	-0.020	0.100
Nitrogen	0.040	0.000	0.040
Sulphur	0.013	0.013	0.026
Ash	0.067	0.000	0.067
	1.000	3.193	4.193
Carbon on dry ash-free basi	0.170		
Analysis of Supplied Air			
Specific Humidity	0.008		
Composition by mass			
Constituent	**Dry Air**	**Humid Air**	
N2	0.76280	0.75670	
O2	0.23290	0.23104	
CO2	0.00300	0.00298	
Ar	0.00130	0.00129	
H2O	0.00000	0.00800	
SO2	0.00000	0.00000	

	1.00000	**1.00000**	
Air required per kg of fuel	13.82	Stoichiometric A/F ratio	kg/kg
Excess Air	1.5		
Actual A/F ratio kg/kg	34.55077		
Exhaust Gases		**Wet Mass**	**Dry Mass**
Constituent	**Mass**	**Composition**	**Composition**
N2	26.18449	0.74001	0.79042
O2	4.78950	0.13536	0.14458
CO2	2.08282	0.05886	0.06287
Ar	0.04456	0.00126	0.00135
H2O	2.25641	0.06377	0.00000
SO2	0.02600	0.00073	0.00078
	35.38377	**1.00000**	**1.00000**
Exhaust Gases			**Volume**
Constituent	**Kg/kmol**	**Mole Fraction**	**Composition**
N2	28	0.02643	0.74275
O2	32	0.00423	0.11888
CO2	44	0.00134	0.03760
Ar	40	0.00003	0.00088
H2O	18	0.00354	0.09956
SO2	64	0.00001	0.00032
		0.03558	1.00000
Mass balance			
Fuel	1.00000		
Supplied Air	34.55077		
	35.55077		
Exhaust Gases	35.38377		
Ash	0.06700		
	35.45077		

Vondracek suggests the following formula for gross calorific value (GCV) of fossil fuels when oxygen content exceeds 10%

GCV = (337 -0.261 C1) C +1130 (H - O/10) + 105 S

GCV is in (kJ/kg). C, H, O, S are percentages on weight basis for carbon, hydrogen, oxygen and sulphur. The net calorific value for a constant pressure combustion is:

NCV = GCV - mc * hfg

mc is the mass of condensate per unit quantity of fuel and hfg is the latent heat of steam at 25 degree Celsius which is 2442 kJ/kg.

Supplied Air Temp.	18		
Fuel Cp	3.2	**kJ/(kg.K)**	
Gross Calorific Value, GCV	41836	**kJ/kg**	
Net Calorific Value, NCV	41680	**kJ/kg**	
Combustion efficiency	0.75		
	Enthalpy	**Mass Flow**	**m*h**

	kJ/kg	kg/s	kJ/s
Supplied Air	38.31	34.55	1323.51
Fuel	64.00	1.00	64.00
Fuel Energy Supplied	41680.38	1.00	31260.28
			32647.79
Exhaust Gases	918.34	35.55	32647.79
Exhaust Gases Temp	671.	**C**	

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Appendix H

A fossil fuel with the following composition by mass:

C 70%; H 18.5%; O 3%; N 4%; S 1.5%; ash 3%

**has been burned in a boiler, when 100% excess air is supplied.
Combustion efficiency is 0.75 Calculate:**

1- the stoichiometric air-to-fuel (A/F) ratio
2- the A/F ratio
3- analysis of combustion products (dry and wet)
4- temperature of exhaust gases

Air is supplied at atmospheric pressure and 18 C with 0.008 specific humidity. The fuel has an average temperature of 35 C when enters the boiler. Use Dulong formula to estimate the net calorific value of the fuel.The specific heat capacity of fuel is 3.2 kJ/kg,K.

Combustion Equations

Combustion equation for coal:

C + O2 => CO2 (12 kg C)+(32 kg O) => (34 kg CO2)

Combustion equation for hydrogen:

2 H2 + O2 => 2 H2O (4 kg H)+(32 kg O) => (36 kg H2O)

Combustion equation for sulphur:

S + O2 => SO2 (32 kg S) + (32 kg O) => (64 kg SO2)

Fuel Analysis			
Constituent	**Mass fraction**	**Required oxygen**	**Product mass**
		kg/kg fuel	**kg/kg fuel**
Carbon	0.700	1.867	2.567
Hydrogen	0.185	1.480	1.665
Oxygen	0.030	-0.020	0.010
Nitrogen	0.040	0.000	0.040
Sulphur	0.015	0.015	0.030
Ash	0.030	0.000	0.030
	1.000	3.342	4.342

Analysis of Supplied Air			
Specific Humidity	0.008		
Composition by mass			
Constituent	**Dry Air**	**Humid Air**	
N2	0.76280	0.75670	
O2	0.23290	0.23104	
CO2	0.00300	0.00298	
Ar	0.00130	0.00129	
H2O	0.00000	0.00800	
SO2	0.00000	0.00000	
	1.00000	**1.00000**	

Air required per kg of fuel	14.46	Stoichiometric A/F ratio	kg/kg
Excess Air	1		
Actual A/F ratio kg/kg	28.92757		
Exhaust Gases		**Wet Mass**	**Dry Mass**
Constituent	**Mass**	**Composition**	**Composition**
N2	21.92942	0.73373	0.78344
O2	3.34167	0.11181	0.11938
CO2	2.65276	0.08876	0.09477
Ar	0.03730	0.00125	0.00133
H2O	1.89642	0.06345	0.00000
SO2	0.03000	0.00100	0.00107
	29.88757	**1.00000**	**1.00000**
Exhaust Gases			**Volume**
Constituent	**Kg/kmol**	**Mole Fraction**	**Composition**
N2	28	0.02620	0.74260
O2	32	0.00349	0.09901
CO2	44	0.00202	0.05716
Ar	40	0.00003	0.00088
H2O	18	0.00353	0.09990
SO2	64	0.00002	0.00044
		0.03529	1.00000
Mass balance			
Fuel	1.00000		
Supplied Air	28.92757		
	29.92757		
Exhaust Gases	29.88757		
Ash	0.03000		
	29.91757		

Dulong suggests the following formula for gross calorific value (GCV) of fossil fuels when oxygen content is less than 10%

GCV = 337 C +1442 (H - O/8) + 93 S

GCV is in (kJ/kg). C, H, O, S are percentages on weight basis for carbon, hydrogen, oxygen and sulphur. The net calorific value for a constant pressure combustion is:

NCV = GCV - mc * hfg

mc is the mass of condensate per unit quantity of fuel and hfg is the latent heat of steam at 25 degree Celsius which is 2442 kJ/kg.

Supplied Air Temp.	18		
Fuel Cp	3.2	**kJ/(kg.K)**	
Gross Calorific Value, GCV	49866	**kJ/kg**	
Net Calorific Value, NCV	49711	**kJ/kg**	
Combustion efficiency	0.75		
	Enthalpy	**Mass Flow**	**m*h**
	kJ/kg	**kg/s**	**kJ/s**

Supplied Air	38.31	28.93	1108.10
Fuel	64.00	1.00	64.00
Fuel Energy Supplied	49710.80	1.00	37283.10
			38455.21
Exhaust Gases	1284.94	29.93	38455.21
Exhaust Gases Temp	964.	**C**	

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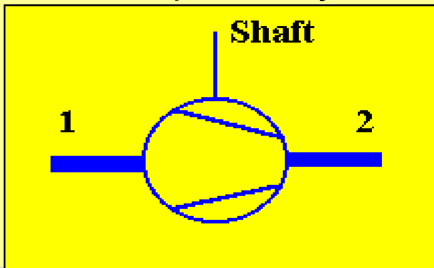
Appendix I

Air at 1.013 bar and 25 C with 0.005 specific humidity enters to a compressor with a pressure ratio of 10/1. The isentropic efficiency of the compressor is 0.82.
Calculate the temperature, specific enthalpy, and specific entropy of air at the outlet.
If the air intake is 5 kg/s, what is the compressor work on the fluid?



Inputs		Units	Error ?
Inlet Pressure	1.013	bar	
Inlet Temperature	25.000	C	
Specific Humidity (moisture content)	0.005		
Isentropic Efficiency	0.820		
Pressure Ratio	10.000		
Mass Flow	5.000	kg/s	

Equations:

$$\gamma = \frac{Cp}{Cp - R}$$

$$\eta_c = \frac{H_{2s} - H_1}{H_2 - H_1} \quad \text{Isentropic Efficiency}$$

$$\frac{T_{2s}}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{Isentropic Process}$$

Outputs			
Inlet Enthalpy	37.759	kJ/kg	
Inlet Entropy	0.088	kJ/(kg.K)	
Inlet Specific Heat Capacity	1.009	kJ/(kg.K)	
Gas Constant	0.288	kJ/(kg.K)	
Gamma	1.399		
Kelvin	273.150	C	
Outlet Pressure	10.130	bar	
Ln(P2/P1)	2.303		
(1-1/Gamma)*'Ln(P2/P1)	0.657		
T2s/T1=....	1.929		
T2s	575.142	degree K	
T2s	301.992	C	
H2s	321.712	kJ/kg	
Outlet Enthalpy	384.043	kJ/kg	
Outlet Temperature	360.970	C	

Outlet Entropy	**0.197**	**kJ/kg**	
Compressor Work on Fluid	**1731.421**	**kW**	

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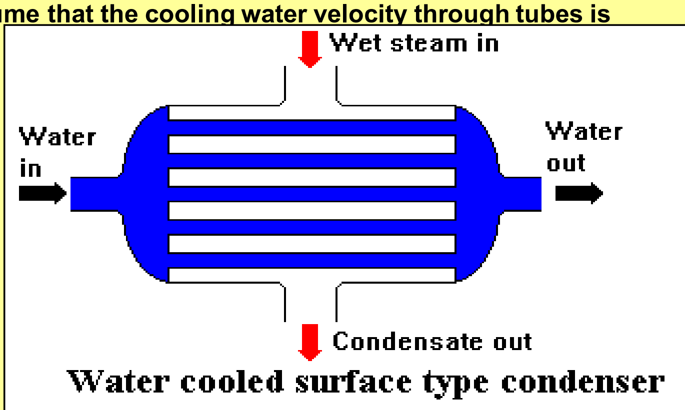
Appendix J

A surface condenser is required to deal with 15 000 kg/h wet steam. Wet steam temperature is 37 C and enters the condenser with 0.95 quality (dryness fraction is 0.95). The water used for cooling has the following data:
-inlet pressure 1.20 bar, inlet temperature 7 C
-outlet pressure 1.013 bar, outlet temperature 22 C
Calculate the flow rate of cooling water and tube surface of the condenser. Assume that the cooling water velocity through tubes is 1.5 m/s



Inputs		Units	Error ?
Wet steam inlet temperature	37	C	
Steam quality	0.95		
Cooling water inlet temperature	7	C	
Cooling water inlet pressure	1.2	bar	
Cooling water outlet temperature	22	C	
Cooling water outlet pressure	1.013	bar	
Steam mass flow	15000	kg/h	
Cooling water speed	1.5	m/s	
Outputs			
Wet steam pressure	0.06274	bar	
Enthalpy of steam at inlet	2448.28	kJ/kg	
Enthropy of condensate	154.92	kJ/kg	
Rejected heat/hour	34400440.44	kJ/h	
Rejected heat/second	9555.68	kW	
Enthalpy of water at inlet	29.53	kJ/kg	
Enthalpy of water at outlet	92.32	kJ/kg	
Water mass flow	547848.07	kg/h	

The overall heat tranfer coefficient can be calculated according to BEAMA or HEI standards.
BEAMA : British Electrical and Allied Manufacturers Association
BEAMA publication on the recomended practice for design of surface type steam condenser
HEI : Heat Exchanger Institute
HEI standards for steam surface condensers

According to BEAMA:

$$U = 2.15\ v^{0.5}(0.7586+0.0135\ T - 0.0001\ T^{2})$$

According to HEA:

$$U = 2.70\ v^{0.5}(0.5707+0.0274\ T - 0.00036\ T^{2})$$

v : Water speed in tubes

T : Condenser temperature [C]
U : Overall heat transfer coefficient [kW/m^2 K]

Outputs		Unit
Heat transfer coeff.(BEAMA)	2.95235	kW/m2,K
Logarithmic mean temp. diff.	49.83	degree K
Required area	64.96	m2

If we use the less conservative HEI method we obtain the following:

Outputs		Unit
Heat transfer coeff.(HEI)	3.60991	kW/m2,K
Required area	53.12	m2

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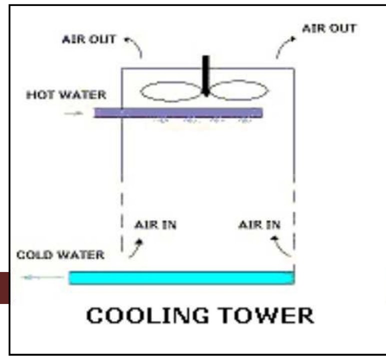
Appendix K

COOLING TOWER

Water inlet mass flow rate	5.5 kg/s
Water inlet temperature	44 C
Induced air flow rate	9 m3/s
Power absorbed by air (power used by fan)	4.75 kW
Inlet air temperature	18 C
Inlet air relative humidity	60 %
Outlet air temperature	26 C
Outlet air relative humidity	100 %
Air pressure thru tower	1.013 bar



Calculate
mass flow rate of make-up water
Final temperature of water leaving the cooling tower

At inlet

Pg	0.021 bar
partial pressure of water	0.012 bar
Partial pressure of other gases in inlet air	1.001 bar
Mass flow rate of air (dry)	10.783 kg/s
Mass flow rate of water in the air	0.083 kg/s
moisture content	0.008

At Exit

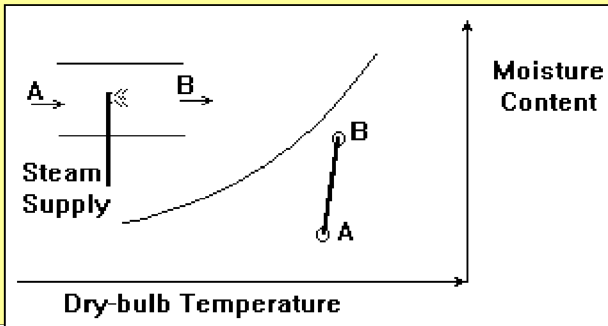
Pg	0.034 bar
specific humidity/moisture content	0.021
Mass flow rate of water in the air	0.230 kg/s
Make-up water req.	0.147 kg/s
Water leaving the cooling tower	5.353 kg/s

Applying steady-flow condition	m[kg/s]	h[kJ/kg]	m*h[kJ/s]
Inlet air	10.866	37.51	407.55
Outlet air	11.013	80.66	888.28
Inlet water	5.500	184.25	1013.38
Outlet water	5.353	100.40	537.40

Outlet water temperature	23.9 C

Appendix L

In an air conditioning plant, air flow rate of 2 kg/s passes through a steam humidifier. Determine the load on the humidifier and the steam supplied. The dry and wet-bulb temperature of the inlet air are 9 C and 3 C respectively. Air leaves the humidifier with a moisture content of 0.008



Inputs		Units
Inlet air, DBT	9.00	C
Inlet air, WBT	3.00	C
Inlet air, mass flow rate	2.00	kg/s
Outlet air, moisture content	0.008	
Atmospheric pressure	1.01	bar

Steam can be directly injected to air stream for air conditioning purposes. In this process, all the latent heat necessary for evaporation of water is added outside the air stream. The supply of water vapor increases the enthalpy of the air. The temperature increase in this process is negligible and it can be assumed as an isothermal process with good approximation. Load on humidifier is:

Q = mA * (hB - hA)

and the steam supplied by humidifier is:

mSteam = mA * (mcB - mcA)

Output		
moisture content of inlet air	0.0022	
Outlet air, DBT	9.0000	
Spec. enthalpy at inlet	14.5	kJ/kg
Spec. enthalpy at outlet	29.2	kJ/kg
Load on the humidifier	29.4102	kW
steam supplied	0.0117	kg/s

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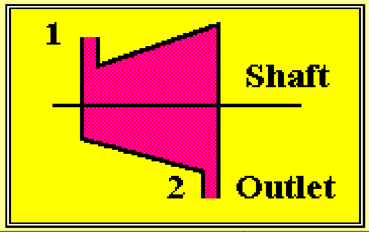
Appendix M

Flue gases at 10.5 bar and 700 C enter to a gas turbine. The turbine has a pressure ratio of 10/1. The isentropic efficiency of the expansion is 0.85. The volumetric composition of flue gases is:
N_2 76.4%; O_2 4.0%; CO_2 15.1%; Ar 0.09%; H_2O 4.2%; SO_2 0.21%
Calculate the temperature, specific enthalpy, and specific entropy of the flue gases at the outlet.
If the intake of hot gases is 5 kg/s, what is the output of the turbine?



Inputs		Units	Error ?
Inlet Pressure	10.5	bar	
Inlet Temperature	700.0	C	
N2 Volumetric %	0.7640		
O2 Volumetric %	0.0400		
CO2 Volumetric %	0.1510		
Ar Volumetric %	0.0009		
H2O Volumetric %	0.0420		
SO2 Volumetric %	0.0021		
Isentropic Efficiency	0.850		
Pressure Ratio	10.000		
Mass Flow	5.000	kg/s	

Equations:

$$\gamma = \frac{C_p}{C_p - R}$$

$$\eta_t = \frac{H_1 - H_2}{H_1 - H_{2s}} \quad \text{Isentropic Efficiency}$$

$$\frac{T_1}{T_{2s}} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} \quad \text{Isentropic Process}$$

Outputs			
Inlet Enthalpy	833.088	kJ/kg	
Gas Constant	0.275	kJ/(kg.K)	
Inlet Entropy	0.726	kJ/(kg.K)	
Inlet Specific Heat Capacity	1.198	kJ/(kg.K)	
Gamma	1.298		
Kelvin	273.150	C	
Outlet Pressure	1.050	bar	
Ln(P1/P2)	2.303		

(1-1/Gamma)*'Ln(P1/P2)	0.528			
T1/T2s=....	1.696			
T2s	573.923	C		
T2s	300.773	C		
H2s	376.256	kJ/kg		
Outlet Enthalpy	444.781	kJ/kg		
Outlet Temperature	363.341	C		
Outlet Entropy	0.871	kJ/(kg.K)		
Turbine Output	1941.536	kW		

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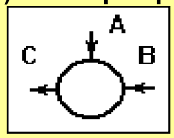
Appendix N

In a Rankine cycle, wet steam (3.5 bar with q = 0.83) is bled off for heating purpose. The bleed steam and feed water (3.5 bar and 135 C) from a pump are mixed in the feed heater.
Determine the quantity of bleed steam.
The steam supplied from the boiler is 5 kg/s



Inputs		Units	Error ?
Pressure at A, B and C	3.5	bar	
Steam quality at A	0.83		
Steam Temp. at B	135	C	
Steam quality at C	0		
Mass Flow	5.00	kg/s	
Outputs			
Spec. enthalpy at A	2366.57	kJ/kg	
Spec. enthalpy at B	567.7011	kJ/kg	
Spec. enthalpy at C	584.27	kJ/kg	
Energy and mass balance			
Eq1: mA + mB - mC = 0			
Eq2: mA*hA + mB*hB - mC*hC = 0			
mass flow of bleed steam	0.046	kg/s	

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Appendix O1

Estimate the specific volume of dichlorodifluoromethane vapor
at 20,67 bar and 366,5 K

Tc	385 K	Critical temperature	Table look up from file:
Pc	41.2 bar	Critical pressure	"Chemical component properties.xls"
Omega	0.176	Acentric factor	Index 212
P	20.67 bar		
T	366.5 K		
R	83.14 cm3.bar/(mol.K)		

Solution:

Tr	0.952
Pr	0.502
Z	0.745

V=ZRT/P	1098 cm3/mol	Lee-Kesler method
V experimental	1109 cm3/mol	Registered Version.
Error	-1.0%	

Temperature range for Lee-Kesler method		Pressure range for Lee-Kesler method	
Tmin	115.5 K	Pmin	0.412 bar
Tmax	1540 K	Pmax	412 bar

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Appendix O2

Estimate the specific volume of the saturated isobutane at 300 K

Tc	408.1 K		
Pc	36.5 bar	T	300 K
Omega	0.283		
R	83.14 cm3.bar/(mol.K)		
Solution:			
Tr	0.735		
Pr	0.084		
Z	0.012	Zc	0.265
		Zc Experimental	0.283
Ps	3.078	Error	-6.3%
Ps experimental	3.704		

V=ZRT/P	97.88 cm3/mol	Vc	246.545 cm3/mol
VL experimental	105.90 cm3/mol	Vc Experimental	263.000 cm3/mol
Error	-7.6%	Error	-6.3%

Vv	6091.78 cm3/mol
Vv experimental	6031.00 cm3/mol
Error	1.0%

Temperature range for Lee-Kesler method		Pressure range for Lee-Kesler method	
Tmin	122.43 K	Pmin	0.365 bar
Tmax	1632.4 K	Pmax	365 bar

Appendix O3

Specific Volume of CHLOROBENZENE at its normal boiling point

Solution:

Fluid name	CHLOROBENZENE					
Fluid index	182					
Tc	359.25	C	Critical temperature (table look up)			
Tc in Kelvin	632.4	K				
Pc	45.2	bar	Critical pressure (table look up)			
P	1.013	bar				
Pr	0.022412					
Acentric Factor	0.249		Acentric factor (table look up)			
Tr	0.640942					
Tb	405.332	K				
Tb(experimental)	131.75	C	404.9	K	Error	0.1%
R	83.14	cm3.bar/(mol.K)				
Z(Liquid)	0.003554					

V=Z*R*T/P=Z*Gc*T/P

V(Liquid)	118.11	cm3/mol
V(Liquid) experimental	115.00	cm3/mol
Error	2.7%	

Temperature range for Lee-Kesler method			Pressure range for Lee-Kesler method		
Tmin	189.72	K	Pmin	0.452	bar
Tmax	2529.6	K	Pmax	452	bar

Appendix O4

Estimate the specific volume of isobutane
case 1- saturated liquid at 310.93 K
case 2- compressed liquid at 310.93 K and 137.9 bar

Solution:

Fluid name	isobutane	
Fluid index	274	
Tc in Kelvin	408.1	K
Pc	36.5	bar
T	310.93	K
P	137.9	bar
Pr	3.78	
Acentric Factor	0.176	
Tr	0.76	
R	83.14	cm3.bar/(mol.K)

Table look up from file:
"Chemical component properties.xls"
Index 274

P_sat(reduced)	0.139353	
P_sat	5.086	bar
P_sat experimental	4.958	bar
Error	2.6%	

Z(T_sat)	0.021138	
V(T_sat)	107.4	cm3/mol
V(T_sat) experimental	108.2	cm3/mol
Error	-0.7%	

Z(P,T)	0.556481	
V(P,T)	104.3	cm3/mol
V(P,T) experimental	102.7	cm3/mol
Error	1.6%	

Temperature range for Lee-Kesler method			Pressure range for Lee-Kesler method		
Tmin	122.43	K	Pmin	0.365	bar
Tmax	1632.4	K	Pmax	365	bar

Appendix O5

Estimate the enthalpy and entropy departures for Propylene
at 398.15 K and 100 bar.
The ideal gas reference pressure for entropy is 1 bar.

Solution:

Fluid Name	Propylene		
Fluid index	416		
Molecular mass	42.081		
Pc	46.2	bar	
Tc	91.85	C	365 K
Acentric fac.	0.148		
P	100	bar	
T	398.15	K	
R	8.314	kJ/(kg.K)	
Pr	2.16		
Tr	1.09		
P0	1.00	bar	

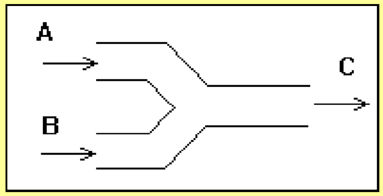
H0-H	240.80	kJ/kg
(H0-H) experimental	244.58	kJ/kg
Error	-1.5%	

S0-S	1.3838	kJ/(kg.K)
(S0-S) experimental	1.4172	kJ/(kg.K)
Error	-2.4%	

Temperature range for Lee-Kesler method			Pressure range for Lee-Kesler method		
Tmin	109.5	K	Pmin	0.462	bar
Tmax	1460	K	Pmax	462	bar

Appendix P

In an air conditioning plant, outdoor air mixes with recirculated air. Calculate the specific enthalpy, moisture content an dry-bulb temperature of the mixed air stream.
Outdoor air:
dry-bulb temp. = 5 C
moisture content = 0.002
mass flow = 2 kg/s
Recirculated air:
dry-bulb temp. = 21 C
moisture content = 0.012
mass flow = 6 kg/s



Inputs		Units
Outdoor air, DBT	5.00	C
Outdoor air, moisture content	0.002	
Outdoor air, mass flow rate	2.00	kg/s
Recirculated air, DBT	21.00	C
Recirculated air, moisture content	0.010	
Recirculated air, mass flow rate	6.00	kg/s
Outputs		
mass flow rate of the mixture	8.00	kg/s
moisture content of the mixture	0.0080	
specific enthalpy of the outdoor air	10.04	kJ/kg
specific enthalpy of the recirculated a	46.43	kJ/kg
specific enthalpy of the mixture	37.33	kJ/kg
Dry-bulb temp. of the mixture	17.04	C

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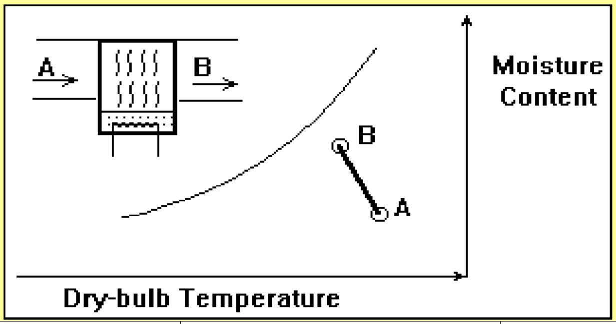
Appendix Q

In an air conditioning plant, air flow rate of 2 kg/s passes through a pan steam humidifier. Determine the load on the humidifier and the steam supplied. The dry and wet-bulb temperature of the inlet air are 9 C and 3 C respectively. Air leaves the humidifier with a moisture content of 0.008



Inputs		Units
Inlet air, DBT	9.00	C
Inlet air, WBT	3.00	C
Inlet air, mass flow rate	2.00	kg/s
Outlet air, moisture content	0.008	
Atmospheric pressure	1.01	bar

A pan steam humidifier uses a heating element inside a water tank. The tank is mounted at the bottom of the air duct. The air flowing over the water surface will cause some evaporative cooling which results in drop of air dry-bulb temperature. The ratio of sensible heat to total heat is approximately 0.2
Load on the humidifier is:

Q = mA * (hB - hA)
and the steam supplied by humidifier is:
mSteam = mA * (mcB - mcA)

Output			
moisture content of inlet air	0.0022		
Outlet air, DBT	12.66	C	Assumed
Spec. enthalpy at inlet	14.5	kJ/kg	
Spec. enthalpy at outlet	32.9	kJ/kg	
Load on the humidifier = total heat	36.8061	kW	
Sensible heat	7.3591	kJ/kg	
Qs / Q = 0.2	0.1999		Goal
Use the solver to reach the goal			
steam supplied	0.0117	kg/s	

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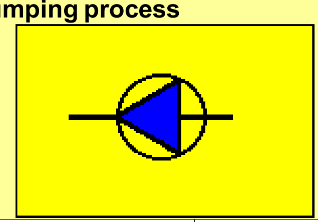
Appendix R

Saturated water is supplied to a feed-pump at 0.035 bar. The outlet pressure is 12 bar.

1-Calculate the input power to the feed-pump if the mass flow of the water is 2 kg/s and the isentropic efficiency of the pump is 0.9
2-Calculate specific enthalpy, specific entropy, specific volume and temperature of the water before and after the pumping process



Inputs		Units	Error ?
Inlet Pressure	0.035	bar	
Saturated Water	0		
Outlet Pressure	12	bar	
Isentropic Efficiency	0.9		
Mass Flow	2	kg/s	
Outputs			
Inlet Enthalpy	111.85	kJ/kg	
Inlet Entropy	0.3907	kJ/(kg.K)	
Inlet Temperature	26.69	C	
Enthalpy of Isentropic Compression	113.20	kJ/kg	
Outlet Enthalpy	113.35	kJ/kg	
Input Power	3.01	kW	
Outlet Temperature	26.79	C	
Outlet Entropy	0.3912	kJ/kg	
Outlet Specific Volume	1.0029	m3/ton	
Inlet Specific Volume	1.0033	m3/ton	

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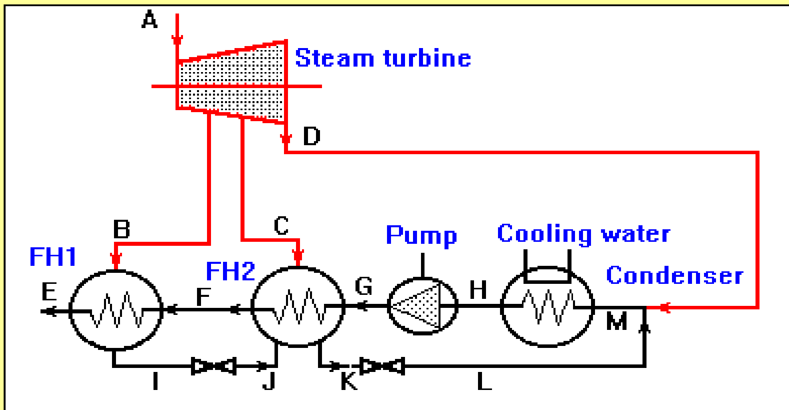
Appendix S

A regenerative steam cycle uses two closed-feed heaters. Determine the amount of steam bled at each stage, the work output of the plant and cycle efficiency. It is known that: pA=40 bar, tA=500 C, pB=10 bar, pC=1.0 bar, pD=0.035 bar. Isenteropic efficiency of the steam turbine and pump are 0.85 and 0.90 respectively. Boiler supplies 10 kg/s steam to the turbine.

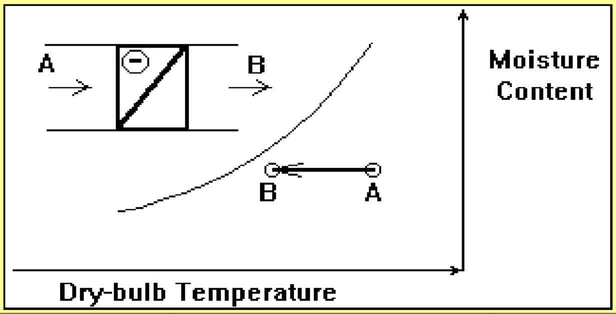


Inputs		Units	Error ?
Pressure at A	40.00	bar	
temperature at A	500.00	C	
Pressure at B	10.00	bar	
Pressure at C	1.00	bar	
Pressure at D	0.035	bar	
Pressure at G	40.00	bar	
Mass flow through the system	10.00	kg/s	
Turbine isentropic eff.	0.85		
Pump isentropic eff.	0.90		
Outputs			
Spec. enthalpy at A	3444.99	kJ/kg	
Spec. entropy at A	7.09	kJ/(kg.K)	
Isentropic enthalpy at B	3032.71	kJ/kg	
Spec. enthalpy at B	3094.55	kJ/kg	
Power generated at stage 1, POW1	3504.33	kW	
Spec. entropy at B	7.20	kJ/(kg.K)	
Isentropic enthalpy at C	2615.07	kJ/kg	
Spec. enthalpy at C	2686.99	kJ/kg	
Power generated at stage 2, POW2	3472.49	kW	
Spec. entropy at C	7.39	kJ/(kg.K)	
Isentropic enthalpy at D	2210.69	kJ/kg	
Spec. enthalpy at D	2282.14	kJ/kg	
Power generated at stage 3, POW3	3003.49	kW	
Spec. enthalpy at H	111.85	kJ/kg	
Spec. entropy at H	0.39	kJ/(kg.K)	
Isentropic enthalpy at G	116.00	kJ/kg	
Spec. enthalpy at G	116.47	kJ/kg	
Power req. for pump	46.21	kW	
For the throttling process, I-J			

hE = hI = hJ	762.61	kJ/kg	
For the throttling process, K-L			
hF = hK = hL	417.51	kJ/kg	
Energy balance on FH1 gives, mB	1.48	kg/s	
Energy balance on FH2 gives, mC	1.10	kg/s	
Net power generated	9934.10	kW	
Cycle efficiency	0.370		

Appendix T

In an air conditioning plant, air flow rate of 2 kg/s passes through a coil. The dry-bulb temperature decreases from 25 C to 10 C. The moisture content of the air is 0.005. Determine the load on the coil. Surface temperature of the coil is above the dew-point temperature i.e. the moisture content is constant.



Inputs		Units
on-coil air, DBT	25.00	C
on-coil air, moisture content	0.005	
on-coil air, mass flow rate	2.00	kg/s
off-coil air, DBT	10.00	C
off-coil air, moisture content	0.005	
off-coil air, mass flow rate	2.00	kg/s
Atmospheric pressure	1.01	bar
Output		
Dew-point temperature	4.0	C
Specific enthalpy of the on-coil air	37.7592	kJ/kg
Specific enthalpy of the off-coil air	22.6280	kJ/kg
Load on the coil	30.2625	kW

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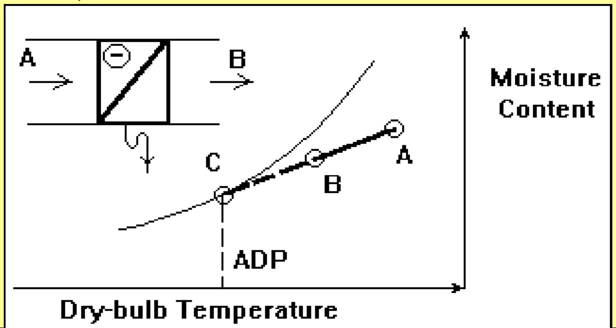
Appendix U

In an air conditioning plant, air flow rate of 2 kg/s passes through a coil. The dry-bulb temperature decreases from 24 C to 12 C. The moisture content of the air decreses from 0.010 to 0.008. Determine the load on the coil, contact factor of the coil and apparatus dew-point temperature, ADP.



Inputs		Units
on-coil air, DBT	24.00	C
on-coil air, moisture content	0.010	
on-coil air, mass flow rate	2.00	kg/s
off-coil air, DBT	12.00	C
off-coil air, moisture content	0.008	
Atmospheric pressure	1.01	bar

The contact factor of a coil is defined as the efficiency for dehumidification. A 100% efficient coil will bring the moisture content of the air to the saturation moisture content at the apparatus dew-point, mcC. The contact factor of the coil can be defined by moisture content differences:

cf = (mcA - mcB)/(mcA - mcC)

or

cf = (hA - hB)/(hA - hC)

Output			
Specific enthalpy of the on-coil air	49.4733	kJ/kg	
Specific enthalpy of the off-coil air	32.2385	kJ/kg	
Load on the coil	34.4695	kW	
Apparatus dew-point moisture content	0.0077		Assumed
Apparatus dew-point temperature	10.4	C	
Apparatus dew-point enthalpy	29.9	kJ/kg	
Coil contact factor Eq1	0.88		
Coil contact factor Eq2	0.88		
Diff = Eq1-Eq2 = 0	0.0003		Goal
Use the solver to reach the goal			

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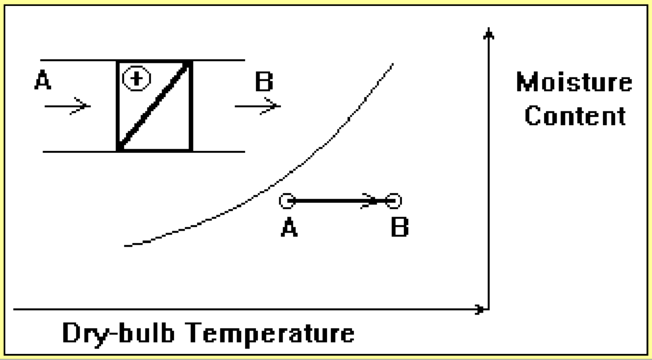
Appendix V

In an air conditioning plant, air flow rate of 2 kg/s passes through a heater battery. The dry-bulb temperature rises from 10 C to 24 C. The moisture content of the air is 0.005. Determine the load on the heater battery.



Inputs		Units
Inlet air, DBT	10.00	C
Inlet air, moisture content	0.005	
Inlet air, mass flow rate	2.00	kg/s
Outlet air, DBT	24.00	C
Outlet air, moisture content	0.005	
Outlet air, mass flow rate	2.00	kg/s
Outputs		
Specific enthalpy of the inlet air	22.6280	kJ/kg
Specific enthalpy of the outlet air	36.7503	kJ/kg
Load on the heater battery	28.2446	kW

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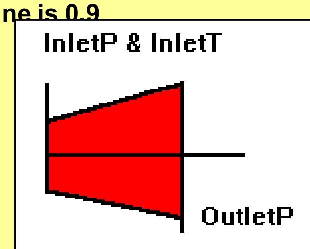
Appendix W

Superheated steam is supplied at 40 bar and 350 C to a single-stage turbine and the condenser pressure is 0.035 bar.

1-Calculate the output power of the turbine if the mass flow of steam is 2 kg/s and the isentropic efficiency of the turbine is 0.9
2-Calculate the dryness fraction at outlet



Inputs		Units	Error ?
Inlet Pressure/Admission Data	40	bar	
Inlet Temperature/Admission Data	350	C	
Outlet Pressure	0.035	bar	
Isentropic Efficiency	0.9		
Mass Flow	2	kg/s	
Outputs			
Inlet Enthalpy	3095.08	kJ/kg	
Inlet Entropy	6.59	kJ/(kg.K)	
Enthropy of Isentropic Expansion	1969.79	kJ/(kg.K)	
Outlet Enthalpy	2082.32	kJ/kg	
Output Power	2025.53	kW	
Dryness Fraction at Outlet	0.81		

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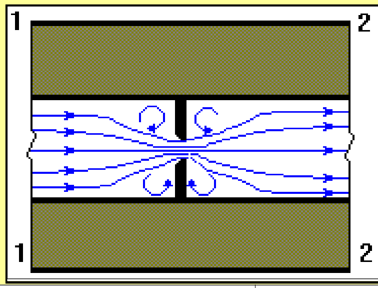
Appendix X

Steam at 7.5 bar with 0.95 dryness fraction is throttled to 4.0 bar. Calculate the specific enthalpy, specific entropy, specific volume and temperature

1- at inlet
2- at outlet

What is the dryness fraction at outlet?



Inputs		Units	Error ?
Inlet Pressure	7.50	bar	
Inlet Dryness Fraction	0.95	C	
Outlet Pressure	4.00	bar	
Outputs			
Inlet Enthalpy	2662.06	kJ/kg	
Inlet Entropy	6.4486	kJ/(kg.K)	
Inlet Specific Volume	242.7108	m3/ton	
Inlet Temperature	167.76	C	
Outlet Enthalpy	2662.06	kJ/kg	
Output Entropy	6.7130	kJ/(kg.K)	
Output Specific Volume	445.8866	m3/ton	
Output Temperature	143.62	C	
Dryness Fraction at Outlet	0.9646		

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